CHAPTER 7: NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE ANALYSIS

7.1 INTRODUCTION

This chapter describes the method for estimating the quantity and value of future national energy savings (NES) from possible standards. The two metrics discussed in this chapter are:

- National Energy Savings, and
- Net Present Value (NPV) of National Energy Savings.

All calculations are performed on a series of Microsoft Excel spreadsheets which are accessible over the Internet. Basic outputs from the spreadsheet calculations are discussed in section 7.4. A more detailed set of results are available in Appendix F. Access to and basic instructions for the spreadsheets are discussed in section 7.5.

7.1.1 Methodology and Definitions

Among the important drivers of energy consumption of central air conditioners and heat pumps are: 1) shipments of air conditioners and heat pumps, 2) how consumers respond to any change in purchase price, operating expense, and household income, and 3) voluntary programs promoting higher energy efficiency products.

The number of air conditioners and heat pumps purchased in future years (shipments) and the effect that purchase price, operating expense, and income has on these purchases are an important component of any estimate of future energy savings. Chapter 6 provides a detailed description of the Shipments Model that are used to forecast future air conditioner and heat pump purchases. Included in the discussion are detailed descriptions of consumers' sensitivities to price, operating expense, and income (otherwise known as elasticities) and how they are captured within the Models. The reader is referred to Chapter 6 for more details regarding the Shipments Model.

As noted in the Chapter 6, for purposes of forecasting shipments, only the residential housing market is considered. Although ignored in the shipments analysis, commercial building applications are accounted for in the NES and NPV analysis by adjusting the annual energy consumption of central air-conditioning and heat pump equipment to reflect their use in commercial buildings.

With regard to voluntary programs, they may increase the share of energy efficient products prior to the implementation date of any new standards. Information from parties involved in market-based initiatives for increasing the sales of high-efficiency models were reviewed but provided no quantifiable measure as to how these programs impact product efficiencies on a national basis[1]. Thus, the impact of market-based initiatives were not explicitly incorporated into any shipments forecast.

Preliminary results are also described here including: energy consumption, monetary value of energy savings, increased purchase prices, and the net present value (difference between value of energy savings and increased purchase prices).

7.2 NATIONAL ENERGY SAVINGS (NES)

7.2.1 NES Definition

This section provides the definition of national energy savings.

National annual energy savings are calculated as the difference between two projections: a base case (without new standards) and a standards case (Eqn 7.1). Positive values of NES correspond to energy savings, that is, energy consumption with standards is less than energy consumption in the base case.

$$NES_y = AEC_{base} - AEC_{standard} \qquad \textbf{(7.1)}$$

Cumulative energy savings are the sum over some period (e.g., 2006-2030) of the annual national energy savings.

$$NES_{cum} = \quad NES_y \qquad \textbf{(7.2)}$$

The national annual energy consumption is calculated according to the following equation:

$$AEC = \quad STOCK_V \cdot UEC_V \qquad \textbf{(7.3)}$$

For the above expressions, the following quantities are required:

AEC	=	Annual energy consumption each year (Quads), summed over vintages of air conditioner or heat pump stocks, $STOCK_V$.
NES	=	Annual national energy savings (Quads)
$STOCK_V$	=	Stock of air conditioners or heat pumps (millions of units) of vintage *V* surviving in the year for which annual energy consumption is being calculated. Vintages range from 1- to 24-years old.
UEC_V	=	Annual energy consumption per air conditioner or heat pump (kWh). [NOTE: electricity consumption is converted from site energy (kWh)

to source energy (Quads) by applying a time dependent conversion factor (Btu/kWh). See discussion of *Source Conversation Factor* in Section 7.2.2.3 below.]

V	=	Year in which the air conditioner or heat pump was purchased as a new unit.
y	=	year in the forecast (e.g., 2006-2030)

7.2.2 NES Inputs

This section provides information about the quantities and assumptions used to calculate NES due to central air conditioner and heat pump standards. For each quantity, the discussion includes:

- definition;
- approach; and
- current assumptions.

The inputs into the NES are listed in Table 7.1 below.

Table 7.1 National Energy Saving Inputs

Input
National Annual Energy Consumption (*AEC*)
National Annual Energy Savings (*NES*)
Source conversion factor (*src_conv*)
Stock of air conditioners or heat pumps ($STOCK_V$)
Annual Energy per Unit (*UEC*)
Shipments

7.2.2.1 National Annual Energy Consumption (*AEC*)

Definition

National energy consumption associated with residential central air conditioners and heat pumps.

Approach

National energy consumption is the product of energy consumption per air conditioner or heat pump multiplied by the number of air conditioners or heat pumps of each vintage. This approach accounts for differences in unit energy consumption from year to year. The calculation procedure for determining the annual energy consumption of air conditioners and heat pumps was shown previously in Eqn 7.3 and is repeated below.

$$AEC = \quad STOCK_V \cdot UEC_V$$

Assumptions

Energy consumption is calculated at the site (i.e., electricity in kWh consumed in the household or commercial building). Primary energy consumption is calculated from site energy consumption by applying a conversion factor to account for losses, such as those associated with the generation, transmission and distribution of electricity. See Section 7.2.2.3, *Source Conversion Factor,* below.

7.2.2.2 National Energy Savings (*NES*)

Definition

Energy savings attributable to the new standards.

Approach

As shown previously in Eqn 7.1, energy savings are calculated as the difference between projected energy consumption in the base case (having no new standards) and the projected energy consumption in the standards case. The equation is repeated below.

$$NES_y = AEC_{base} - AEC_{standard}$$

Assumptions

Simple subtraction between two projections.

7.2.2.3 Source Conversion Factor

Definition

For electricity, this is the factor by which site kWh is multiplied to obtain primary (source) Btu. The source conversion factor accounts for losses in generation, transmission and distribution.

Approach

After calculating energy savings at the site, multiply those site energy savings by a conversion factor to obtain primary energy consumption, usually expressed in Quads (quadrillion Btu). This conversion permits comparison across fuels by taking account of the heat content of different fuels and the efficiency of different energy conversion processes.

Assumptions

Based on recommendations of the Advisory Committee on Appliance Energy Efficiency Standards, conversion factors have been determined according to the following method:

1. Start with an integrated projection of electricity supply and demand (e.g., the National Energy Modeling System (NEMS) Annual Energy Outlook reference case), and extract the source energy consumption.

2. Estimate projected energy savings due to possible standards for each year (e.g., using the National Energy Savings (NES) spreadsheet model).

3. Feed these energy savings back to NEMS as a new scenario, specifically a deviation from the reference case, to obtain the corresponding source energy consumption.

4. Obtain the difference in source energy consumption between this standard level scenario and the reference case.

5. Divide the source energy savings in Btu, adjusted for class specific transmission and distribution losses, by the site energy savings in kilowatt-hours to provide the time series of conversion factors in Btu per kilowatt-hour.

NEMS cannot adjust for class specific transmission losses, and assumes overall transmission and distribution losses of 10%. Based on the above losses, the conversion factor would be the marginal plant heat rate times 1.10.

The base conversions were based on the maximum energy savings possible (i.e., 18 SEER standard-level) to avoid "noise" within NEMS. At small differences in energy savings, the accuracy within NEMS is less. NEMS drops the least efficient power producers (cost wise) first, which are not necessarily the least polluting power plants.

Table 7.2 shows the resulting conversion factors and how they change over time.

Table 7.2 Site-to-Source Conversion Factors

Year	Site-to-Source Conversion Factor *Btu/kWh*
2000	11,500
2001	11,500
2002	11,500
2003	11,500
2004	11,500
2005	11,500
2006	11,450
2007	11,350
2008	11,100
2009	10,453
2010	8,846
2011	7,239
2012	6,892
2013	6,792
2014	6,792
2015	6,724
2016	6,308
2017	5,714
2018	5,519
2019	5,519
2020	5,519

7.2.2.4 Stock of Air Conditioners and Heat Pumps by Vintage ($STOCK_V$)

Definition

Number of air conditioners or heat pumps purchased in a particular year that survive in a later year. The vintage is the age of the air conditioner or heat pump (1-year old up to 24-year old).

Approach

The NES spreadsheet models keep track of the number of air conditioners or heat pumps purchased each year. Air conditioners and heat pumps are assumed to have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is the survival function. The lifetime was based on a survey performed for the Electric Power Research Institute of 2,184 heat pump installations in a seven-state region of the United States[2].

Assumption

For air conditioners and heat pumps, lifetimes range from 1 to 24 years, with an average of 18.4 years (see Chapter 5, Section 5.2.3.10, *Lifetime and Compressor Replacement Costs*). The retirement or survival function is presented below in Figure 7.1.

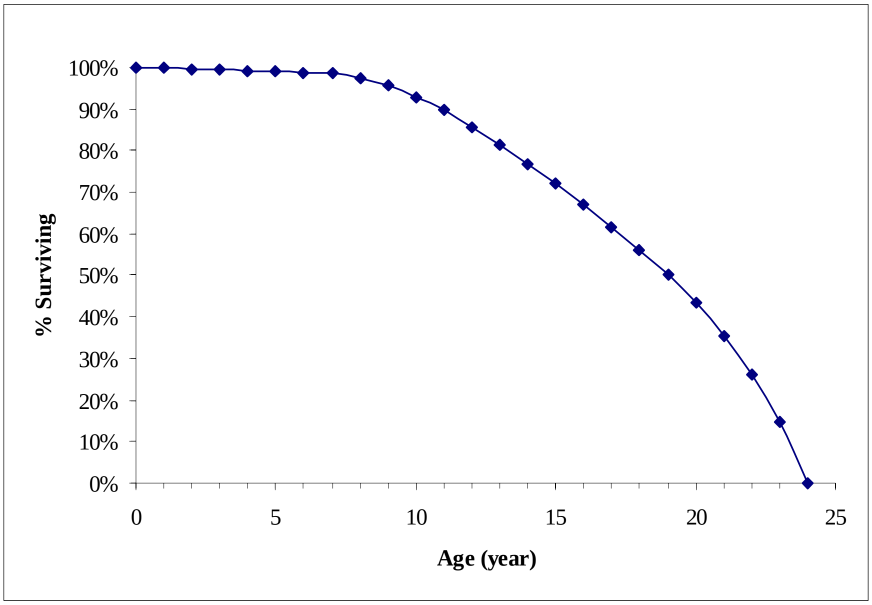

Figure 7.1 Retirement Function for Central Air Conditioners and Heat Pumps

7.2.2.5 Annual Energy per Unit (*UEC*)

Definition

Energy consumed per air conditioning or heat pump unit.

Approach

Energy consumed per unit varies from year to year due to the change in the level of efficiency of new units being shipped. The energy consumption for a particular year is calculated relative to the energy use and efficiency associated with the existing equipment stock equipment. For central air conditioners, the following equation is used to determine the annual energy use per unit for a particular year.

$$UEC_{CAC,V} = UEC_{CAC,stock} \cdot \frac{SEER_{CAC,\ stock}}{SEER_{CAC,V}} \qquad \textbf{(7.4)}$$

Where,

$UEC_{CAC,V}$ = annual energy consumption of a central air conditioner in a particular vintage year,

$UEC_{CAC,stock}$ = annual energy consumption of central air conditioners based on the building stock equipped with central air conditioners,

$SEER_{CAC,stock}$ = SEER of central air conditioners based on building stock equipped with central air conditioners, and

$SEER_{CAC,V}$ = shipment *weighted-average* SEER in a particular vintage year.

For heat pumps, the following equation is used to determine the annual energy use per unit for a particular year.

$$UEC_{HP,V} = UEC_{HP,stock-cool} \cdot \frac{SEER_{HP,stock}}{SEER_{HP,V}} + UEC_{HP,stock-heat} \cdot \frac{HSPF_{HP,stock}}{HSPF_{HP,V}} \qquad \textbf{(7.5)}$$

Where,

$UEC_{HP,V}$ = annual energy consumption of a heat pump in a particular vintage year,
$UEC_{HP,stock\text{-}cool}$ = annual space-cooling energy consumption of heat pumps based on the building stock equipped with heat pumps,
$SEER_{HP,stock}$ = SEER of heat pumps based on the building stock equipped with heat pumps,
$SEER_{HP,V}$ = shipment *weighted-average* SEER of heat pumps in a particular vintage year,
$UEC_{HP\text{-}stock\text{-}heat}$ = annual space-heating energy consumption of heat pumps based on the building stock equipped with heat pumps,
$HSPF_{HP,stock}$ = HSPF of heat pumps based on the building stock equipped with heat pumps, and
$HSPF_{HP,V}$ = shipment *weighted-average* HSPF of heat pumps in a particular vintage year.

The above equations are used to derive annual energy consumption values for each of the four primary product classes: split air conditioners, split heat pumps, single package air conditioners, and single package heat pumps.

As described in Chapter 5, both the energy use and efficiency associated with existing equipment stock in residential buildings are based on data from the 1997 Residential Energy Consumption Survey (RECS) while the commercial building analysis provides the energy use and efficiency associated with exiting equipment stock in commercial buildings. The residential energy use and efficiency data are disaggregated by Census Division while nationally representative values are used for the commercial equipment stock.

Shipment *weighted-average* efficiencies (variables $SEER_{CAC,V}$, $SEER_{HP,V}$, and $HSPF_{HP,V}$) are derived from a distribution of efficiencies (i.e., the percentage of shipments which occur in incremental SEER bins over the range from the minimum standard to 18 SEER). Unique efficiency distributions are defined for each of the four primary product classes. As a result, forecasted energy savings and NPVs can be disaggregated by product class. For years preceding 1992 (1951 through 1991), we assume a distribution of efficiency levels which is normally distributed and constrained to have efficiencies between 5 and 18 SEER, inclusive. The normal distribution function is assumed to have a standard deviation of 1.5 SEER and an average efficiency of 8.8 SEER in 1991. Between the years 1992 and 1997, equipment efficiencies have remained relatively constant based on Air-

Conditioning & Refrigeration Institute (ARI) data. Thus, efficiencies are assumed to remain constant from 1992 to the year in which new standards are assumed to become effective (i.e., 2006). Equipment efficiency distributions in the years after new standards take effect are modeled with the following three *efficiency scenarios*: NAECA, Roll-up, and Shift. Post-standard equipment efficiency distributions are assumed to remain constant through the year 2030. Each of the *efficiency scenarios* are described in more detail later.

Assumptions

Table 7.3 shows the energy use and efficiency associated with the existing equipment stock. Residential energy use and efficiency are disaggregated into the nine Census Divisions while only nationally representative values are shown for commercial applications. *Weighted-average* values for the entire equipment stock are also presented and are based on the share captured by each residential Census Division and the commercial sector. Residential Census Division shares are based on data from the 1997 RECS[3]. Based on the assumption that 10% of the equipment stock are used in commercial applications, the residential Census Division shares are normalized to total 90% of the entire equipment stock. The *weighted-average* energy use and efficiency values are more extensively described in Chapter 5 (see Chapter 5, Sections 5.2.3.1, *Baseline Annual Space-Cooling Energy Use* and 5.2.3.3, *Baseline Annual Space-Heating Energy Use*).

Table 7.3 Annual Energy Use and Efficiencies for Residential and Commercial Equipment Stock

	Residential Disaggregated by Census Division										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Comm.**	**Weighted-Average[a]**
Central Air Conditioners											
Share	0.9%	8.5%	18.6%	10.1%	17.7%	7.0%	15.7%	3.9%	7.7%	10.0%	-
UEC (kWh/yr)	812	1403	1232	1820	2913	2859	3760	2823	1313	5824	2637
SEER	8.76	9.19	9.11	9.07	9.01	9.23	9.15	9.18	8.79	9.05	9.08
Heat Pumps											
Share	0.3%	3.5%	2.6%	0.8%	55.5%	10.7%	7.1%	4.3%	5.3%	10.0%	-
Cooling UEC (kWh/yr)	503	1781	1385	2651	2484	3242	4033	2917	733	5824	2877
Heating UEC (kWh/yr)	6868	6010	7449	821	3054	5550	3291	4475	4347	2654	3640
SEER	8.55	8.83	9.73	8.88	9.30	9.42	9.31	8.82	9.21	9.11	9.26
HSPF	6.50	6.59	6.90	6.61	6.80	6.81	6.74	6.58	6.74	6.70	6.77

[a] Weighted-average values differ from those used in LCC analysis. Residential households excluded from the LCC analysis based on indeterminable marginal electricity prices are included in the NES and NPV analysis.

Table 7.4 shows the efficiency distributions used in the NES and NPV analysis for central air conditioners and heat pumps for the years 1992 through 2006. As noted earlier, efficiency distributions are based on ARI data and are defined for each product class. Shipment-weighted efficiency values are also provided in Table 7.4. Shipment weighted efficiencies are more extensively described in Chapter 5 (see Chapter 5, Sections 5.2.3.1, *Baseline Annual Space-Cooling Energy Use* and 5.2.3.3, *Baseline Annual Space-Heating Energy Use*). But note, the shipment-weighted efficiencies resulting from the distributions below are different from those used in LCC analysis due to the simplifying assumption for the NES and NPV analyses that efficiencies have remained constant between 1992 through 2006.

Table 7.4 Assumed Product Class Efficiency Distributions for the years 1992 through 2006

	SEER Bins							Weighted-Efficiency	
	9 - 9.9	10 - 10.9	11 - 11.9	12 - 12.9	13 - 13.9	14 - 14.9	15 - 15.9		
	HSPF Bins								
Product Class	6.5 - 6.7	6.8 - 7.0	7.1 - 7.3	7.4 - 7.6	7.7 - 7.9	8.0 - 8.1	8.2 - 8.3	**SEER**	**HSPF**
Split A/C	0.0%	79.7%	4.1%	13.7%	1.5%	0.9%	0.1%	10.7	-
Package A/C	7.2%	77.9%	4.2%	8.2%	2.5%	0.0%	0.0%	10.5	-
Split HP	0.1%	62.3%	7.7%	24.7%	4.1%	0.9%	0.3%	11.0	7.1
Package HP	2.0%	68.6%	5.1%	24.3%	0.0%	0.0%	0.0%	10.8	7.1

Equipment efficiency distributions for the years after new standards take effect are modeled with the following three *efficiency scenarios*:

- **NAECA**: The *NAECA scenario* is named after the legislation which promulgated minimum efficiency standards for central air conditioners and heat pumps. The *NAECA* scenario forecasts that equipment efficiencies after adoption of new standards would change in the same pattern as the efficiency changes that occurred in 1992 when minimum efficiency standards first took effect.

- **Roll-up**: The *Roll-up* scenario simply moves equipment from efficiency levels that exist below the modeled standard level to the SEER value of the new standard. For example, in the case of a 12 SEER standard, if 60% of shipments have efficiencies below 12 SEER, all those shipments are moved to the 12 SEER level without affecting the efficiency distribution above 12 SEER.

- **Shift**: The *Shift* scenario retains the pattern of the existing efficiency distribution but simply re-orients that distribution at and above the new minimum standard that is being modeled.

Tables 7.5 through 7.7 show the efficiency distributions under each of the above *efficiency scenarios* for standard-levels of 11 through 13 SEER, respectively. Post-standard equipment efficiency distributions are assumed to remain constant through the year 2030. Because the maximum technologically feasible efficiency level is assumed to be 18 SEER, efficiencies are not allowed to extend past the "18-18.9 SEER" efficiency bin. Thus, in modeling an18 SEER standard-level, the entire efficiency distribution for all product classes regardless of efficiency scenario is assumed to reside in the "18-18.9 SEER" bin.

Table 7.5 Post-Standard Product Class Efficiency Distributions: 11 SEER Standard-Level

	SEER Bins							Weighted-Efficiency	
	11 - 11.9	12 - 12.9	13 - 13.9	14 - 14.9	15 - 15.9	16 - 16.9	17 - 17.9		
	HSPF Bins								
Product Class	7.1 - 7.3	7.4 - 7.6	7.7 - 7.9	8.0 - 8.1	8.2 - 8.3	8.4 - 8.5	8.6 - 8.7	**SEER**	**HSPF**
NAECA Efficiency Scenario									
Split A/C	77.8%	15.7%	3.5%	2.9%	0.1%	0.0%	0.0%	11.6	-
Package A/C	83.4%	10.2%	4.5%	2.0%	0.0%	0.0%	0.0%	11.5	-
Split HP	64.1%	26.7%	6.1%	2.9%	0.3%	0.0%	0.0%	11.7	7.4
Package HP	69.7%	26.3%	2.0%	2.0%	0.0%	0.0%	0.0%	11.6	7.3
Roll-up Efficiency Scenario									
Split A/C	83.8%	13.7%	1.5%	0.9%	0.1%	0.0%	0.0%	11.4	-
Package A/C	89.4%	8.2%	2.5%	0.0%	0.0%	0.0%	0.0%	11.4	-
Split HP	70.1%	24.7%	4.1%	0.9%	0.3%	0.0%	0.0%	11.6	7.3
Package HP	75.7%	24.3%	0.0%	0.0%	0.0%	0.0%	0.0%	11.5	7.3
Shift Efficiency Scenario									
Split A/C	79.7%	4.1%	13.7%	1.5%	0.9%	0.1%	0.0%	11.7	-
Package A/C	84.0%	4.6%	8.8%	2.7%	0.0%	0.0%	0.0%	11.6	-
Split HP	62.3%	7.7%	24.7%	4.1%	0.9%	0.3%	0.0%	12.0	7.4
Package HP	70.0%	5.2%	24.7%	0.0%	0.0%	0.0%	0.0%	11.8	7.4

Table 7.6 Post-Standard Product Class Efficiency Distributions: 12 SEER Standard-Level

	SEER Bins							Weighted-Efficiency	
	12 - 12.9	13 - 13.9	14 - 14.9	15 - 15.9	16 - 16.9	17 - 17.9	18 - 18.9		
	HSPF Bins								
Product Class	7.4 - 7.6	7.7 - 7.9	8.0 - 8.1	8.2 - 8.3	8.4 - 8.5	8.6 - 8.7	8.8 - 8.9	**SEER**	**HSPF**
NAECA Efficiency Scenario									
Split A/C	91.5%	3.5%	2.9%	2.1%	0.0%	0.0%	0.0%	12.4	-
Package A/C	91.5%	4.5%	2.0%	2.0%	0.0%	0.0%	0.0%	12.4	-
Split HP	88.8%	6.1%	2.9%	2.3%	0.0%	0.0%	0.0%	12.5	7.6
Package HP	94.0%	2.0%	2.0%	2.0%	0.0%	0.0%	0.0%	12.4	7.5
Roll-up Efficiency Scenario									
Split A/C	97.5%	1.5%	0.9%	0.1%	0.0%	0.0%	0.0%	12.3	-
Package A/C	97.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	12.3	-
Split HP	94.8%	4.1%	0.9%	0.3%	0.0%	0.0%	0.0%	12.3	7.5
Package HP	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.3	7.5
Shift Efficiency Scenario									
Split A/C	79.7%	4.1%	13.7%	1.5%	0.9%	0.1%	0.0%	12.7	-
Package A/C	84.0%	4.6%	8.8%	2.7%	0.0%	0.0%	0.0%	12.6	-
Split HP	62.3%	7.7%	24.7%	4.1%	0.9%	0.3%	0.0%	13.0	7.7
Package HP	70.0%	5.2%	24.7%	0.0%	0.0%	0.0%	0.0%	12.8	7.6

Table 7.7 Post-Standard Product Class Efficiency Distributions: 13 SEER Standard-Level

	SEER Bins						Weighted-Average Efficiency	
	13 - 13.9	14 - 14.9	15 - 15.9	16 - 16.9	17 - 17.9	18 - 18.9		
	HSPF Bins							
Product Class	7.7 - 7.9	8.0 - 8.1	8.2 - 8.3	8.4 - 8.5	8.6 - 8.7	8.8 - 8.9	**SEER**	**HSPF**
NAECA Efficiency Scenario								
Split A/C	93.0%	2.9%	2.1%	2.0%	0.0%	0.0%	13.4	-
Package A/C	94.0%	2.0%	2.0%	2.0%	0.0%	0.0%	13.4	-
Split HP	92.9%	2.9%	2.3%	2.0%	0.0%	0.0%	13.4	7.8
Package HP	94.0%	2.0%	2.0%	2.0%	0.0%	0.0%	13.4	7.8
Roll-up Efficiency Scenario								
Split A/C	99.0%	0.9%	0.1%	0.0%	0.0%	0.0%	13.3	-
Package A/C	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.3	-
Split HP	98.9%	0.9%	0.3%	0.0%	0.0%	0.0%	13.3	7.8
Package HP	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.3	7.8
Shift Efficiency Scenario								
Split A/C	79.7%	4.1%	13.7%	1.5%	0.9%	0.1%	13.7	-
Package A/C	84.0%	4.6%	8.8%	2.7%	0.0%	0.0%	13.6	-
Split HP	62.3%	7.7%	24.7%	4.1%	0.9%	0.3%	14.0	8.0
Package HP	70.0%	5.2%	24.7%	0.0%	0.0%	0.0%	13.8	7.9

7.2.2.6 Shipments

See Chapter 6 for an extensive discussion of how shipment forecasts for central air conditioners and heat pump were conducted.

7.2.3 Results

See section 7.4.

7.3 NET PRESENT VALUE (NPV)

7.3.1 NPV Definition

NPV is the value in the present time of a time series of costs and savings. Net present value is described by the equation:

$$NPV = PVS - PVC \qquad \textbf{(7.6)}$$

Where,

PVS = present value of electricity savings and

PVC = present value of equipment costs including installation.

PVS and *PVC* are determined according to the following expressions:

$$PVS = \quad Total\,Operating\,Cost\,Savings_y \cdot Discount\ Factor_y \tag{7.7}$$

$$PVC = \quad Total\ Equipment\ Cost_y \cdot Discount\ Factor_y \tag{7.8}$$

Where,

y = years (from effective date of standard to the year when units purchased in 2030 retire)

The net present value is calculated from the projections of national expenditures for central air conditioners and heat pumps, including purchase price (including equipment and installation price) and operating costs (including electricity, repair, and maintenance costs). Costs and savings are calculated as the difference between a new standards case and a base case without those new standards. Future costs and savings are discounted to the present.

A discount factor is calculated from the discount rate and the number of years between the "present" (year to which the sum is being discounted) and the year in which the costs and savings occur. The net present value is the sum over time of the discounted net savings.

Assumptions regarding *NPV* are contained in the terms *PVC* and *PVS*, which are discussed below. *NPV* is the value today of a future stream of savings less expenditures.

7.3.2 NPV Inputs

This section provides information about the quantities and assumptions used to calculate NPV due to central air conditioner and heat pump standards. For each quantity, the discussion includes:

- definition;
- approach; and
- current assumptions.

Table 7.8 summarizes the inputs to the NPV calculation.

Table 7.8 Net Present Value Inputs

Input
Discount Factor
Net Present Value (*NPV*)[a]
Present Value of Costs (*PVC*)[b]
Present Value of Savings (*PVS*)[c]
Total Equipment Cost_y
Total Operating Cost Savings_y

7.3.2.1 Discount Factor

Definition

The factor by which to multiply monetary values in one year, in order to determine the present value in a different year. Discount Factor is also described by the equation:

$$Discount\ Factor = \frac{1}{(1 + Discout\ Rate)^{(year - present\ year)}} \tag{7.9}$$

Approach

For example, to discount monetary values in the year 2000 to the value in year 1998 assuming a discount rate of 7% equals $1/(1.07)^2$ or 0.873.

Assumptions

The discount rate is assumed to be 7% real[d]. The present year is defined to be 1998, for consistency with the year in which the manufacturing cost data were collected.

7.3.2.2 Present Value of Costs (*PVC*)

Definition

Total equipment cost, discounted to the present, and summed over the time period (from assumed effective date of standards (2006) to the year 2030).

---

[a] Referred to in the NES spreadsheets as *Net Present Benefit*.

[b] Referred to in the NES spreadsheet as *Total Equipment Cost* (discounted).

[c] Referred to in the NES spreadsheet as *Total Operating Saving* (discounted).

[d] Used by DOE in previous rulemaking for the National Impact Analysis. Higher and lower values can be used as sensitivities (i.e., to bound a range of discount rates).

Approach

Costs are typically increases in purchase price (including both equipment and installation price) associated with the higher energy efficiency of central air conditioners and heat pumps purchased in the standards case compared to the base case. *Total Equipment Costs* are calculated as the difference in purchase price for new equipment purchased each year, multiplied by the shipments in the standards case[e].

Assumptions

The primary assumption made in calculating *PVC* lies in determining the discount factor to be applied. Here the discount factor is taken to be 7% (see also Section 7.3.2.1, *Discount Factor*, above). In addition, see Section 7.3.2.4, *Total Equipment Cost*, below.

7.3.2.3 Present Value of Savings (*PVS*)

Definition

Annual operating cost savings (difference between base case and standards case) discounted to the present, and summed.

Approach

Savings are typically decreases in operating costs (including electricity, repair, maintenance, and compressor replacement) associated with the higher energy efficiency of central air conditioners and heat pumps purchased in the standards case compared to the base case. *Total Operating Cost Savings* is the product of savings per unit times number of units of each vintage surviving in a particular year. Equipment consume energy over their entire lifetime, in some cases including energy consumed after year 2030.

Net savings each year are calculated as the difference between *Total Operating Cost Savings* and *Total Equipment Costs*.[f] The savings are calculated over the life of the appliance, accounting for the energy rates each year.

Assumptions

As with *PVC*, the primary assumption made in calculating *PVS* lies in determining the discount factor to be applied. Here the discount factor is taken to be 7% (see also Section 7.3.2.1,

---

[e] Counting the reduction in energy consumption from a reduction in shipments as a savings would be incorrect. If standards cause a decrease in shipments, then using the lower shipments in the standards case reduces the NPV appropriately. To illustrate with an extreme example, if standards cause shipments to be zero, then NPV is zero, no matter what the shipments were in the base case. Using the shipments from the standards case avoids miscounting any reduction in shipments due to standards as a savings.

[f] In the NES spreadsheet, *Total Equipment Costs* are expressed as a negative number (the difference between the base case and the standards case) then summed with *Total Operating Cost Savings* (the difference between base case and the standards case).

Discount Factor, above). In addition, see Section 7.3.2.5, *Total Operating Cost Savings*, below.

7.3.2.4 Total Equipment Cost

Definition

Annual change in purchase price (difference between base case and standards case), multiplied by shipments in the standards case.

Approach

Purchase price per central air conditioner or heat pump in the standards case is subtracted from purchase price per central air conditioner or heat pump in the base case for one year. The result is multiplied by the projected shipments in that year.

Assumptions

The purchase price includes both the equipment and installation price. For purposes of calculating the annual change in purchase price, mean equipment and installation prices are used. Mean equipment prices are based on mean manufacturer costs (see Chapter 5, Sections 5.2.2.1, *Baseline Manufacturer Cost* and 5.2.2.2, *Standard-Level Manufacturer Cost Multipliers*) multiplied by mean markup values and the mean sales tax (see Chapter 5, Sections 5.2.2.3, *Manufacturer Markup*, 5.2.2.4, *Distributor Markup*, and 5.2.2.5, *Dealer Markup*, Section 5.2.2.6, *Builder Markup* and Section 5.2.2.7, *Sales Tax*). Installation prices are based on the mean values associated with the installation of split system and single package central air conditioners and split system and single package heat pumps and are assumed not to vary with efficiency (see Chapter 5, Section 5.2.2.8, *Installation Cost*). Table 7.9 shows the resulting mean purchase prices (also known as total installed consumer cost) for split system and single package central air conditioners and heat pumps by standard level. Note that for efficiencies between 15 and 18 SEER, mean purchase prices are identical. Because manufacturer cost multipliers were provided only up through 15 SEER, higher efficiency equipment was assumed to have the same purchase price.

Table 7.9 Mean Purchase Prices for Central Air Conditioners and Heat Pumps

Standard Level	Split A/C	Package A/C	Split HP	Package HP
	ARI	ARI	ARI	ARI
SEER	*1998$*	*1998$*	*1998$*	*1998$*
10	$2,236	$2,607	$3,668	$3,599
11	$2,357	$2,795	$3,779	$3,760
12	$2,510	$2,903	$3,933	$3,920
13	$2,715	$3,229	$4,155	$4,287
14[a]	$3,020	$3,466	$4,376	$4,458
15	$3,302	$3,822	$4,873	$4,894
16	$3,302	$3,822	$4,873	$4,894
17	$3,302	$3,822	$4,873	$4,894
18	$3,302	$3,822	$4,873	$4,894

[a] Based on ARI shipment-weighted mean cost data. The manufacturer cost multipliers for 14 SEER are: 2.03 for splt a/c, 1.87 for package a/c, 1.64 for split heat pump, and 1.75 for package heat pump.

As part of the calculation of the annual change in purchase price, historical and future purchase prices are determined for years dating back to 1951. The resulting *weighted-average* purchase price is determined through a matrix multiplication based on the efficiency distribution for that year (refer back to Section 7.2.2.5, *Annual Energy per Unit (UEC)*) and the purchase price corresponding to each incremental efficiency bin within the distribution. For equipment efficiencies below the existing minimum efficiency (i.e., 10 SEER), the purchase price is assumed to equal that of the existing minimum efficiency equipment in 1998$ as reported in Table 7.9. Note, that although equipment cost data are determined for years preceding the effective date of the standard (i.e., 2006), only the post-standard equipment cost data are critical for determining the national NPV.

Assumptions regarding shipments and the development of shipments forecasts are extensively discussed in Chapter 6.

7.3.2.5 Total Operating Cost Savings

Definition

Annual national operating cost savings, calculated as the difference between total operating cost in the base case minus total operating cost in the standards case.

Approach

Operating expense per central air conditioner or heat pump in the standards case is subtracted from operating expense per central air conditioner or heat pump in the base case for one year. The result is multiplied by the projected shipments in that year. Positive values are savings (e.g., operating costs in the standards case are lower than in the base case).

Assumptions

Operating costs consist of annual electricity, repair, and maintenance costs. In addition, compressor replacement costs are taken into account. For purposes of calculating the annual national operating cost savings, the mean annual electricity, repair, maintenance, and compressor replacement costs for each efficiency level are used.

Mean annual electricity costs for any given year are based upon the annual energy consumption per central air conditioner or heat pump unit for that year (see Section 7.2.2.5, *Annual Energy per Unit (UEC)*) multiplied by the associated energy price. Marginal electricity prices rather than average electricity prices are used in the calculation of the operating cost savings (see Chapter 5, Section 5.2.3.6, *Marginal Electricity Price*). For future years beyond 1998 and to the year 2030, electricity price trends as forecasted in the *Annual Energy Outlook (AEO) 2000* are used to estimate the marginal energy price for those years (see Chapter 5, Section 5.2.3.7, *Electricity Price Trend*).

Mean annual repair, maintenance, and compressor replacement costs are reported in Chapter 5. Since repair costs are assumed to be a function of equipment price, these costs vary with efficiency (see Chapter 5, Section 5.2.3.8, *Repair Cost*). Compressor replacement costs, although not a function of equipment price, do vary with efficiency (see Chapter 5, Section 5.2.3.10, *Lifetime and Compressor Replacment Cost*). As noted in Chapter 5, compressor replacement is assumed to take place in the 14^{th} year of the central air conditioner or heat pump's life. Maintenance costs are assumed to remain constant Compressor (see Chapter 5, Section 5.2.3.9, *Maintenance Cost*).

As part of the calculation of the annual change in electricity, repair, maintenance, and compressor replacement cost, historical and future costs are determined for years dating back to 1951. The resulting *weighted-average* costs are determined through a matrix multiplication based on the efficiency distribution for that year (refer back to Section 7.2.2.5, *Annual Energy per Unit (UEC)*, Table 7.4) and the costs corresponding to each incremental efficiency bin within the distribution. For equipment efficiencies below the existing minimum efficiency (i.e., 10 SEER), the repair, maintenance, and compressor replacement costs are assumed to equal that of the existing minimum efficiency equipment in 1998$ as reported in Table 7.9. Note, that although electricity, repair, maintenance, and compressor replacement cost data are determined for years preceding the effective date of the standard (i.e., 2006), only the post-standard cost data are critical for determining the national NPV.

Assumptions regarding shipments and the development of shipments forecasts are extensively discussed in Chapter 6.

7.4 NES AND NPV RESULTS

The NES spreadsheets offer a range of possible outputs, all of which depend on the assumptions used in deriving the results. Table 7.10 summarizes the assumptions used in the NES calculations for this analysis. Most of the assumptions have been discussed earlier in Sections 7.2.2, *NES Inputs*, and 7.3.2, *NPV Inputs*.

7.4.1 Assumptions

Assumptions regarding the inputs to the NES model are summarized in Table 7.10.

Table 7.10 NES Model Inputs and Assumptions

Parameter	Data Description
Shipments	Annual shipments from shipments model.
Effective Date of Standard	2006.
Historical Efficiencies (extending through the assumed effective date of a new standard (2006))	Based on the use of efficiency distributions. **1951-1991**: Assumed efficiency trend of 0.1 SEER per year. **1992-2006**: Based on ARI data and assumed to remain constant over the time period with resulting *weighted-average* efficiencies of 10.4 SEER for split a/c, 10.3 SEER for package a/c, 10.9 SEER / 7.1 HSPF for split heat pump, and 10.8 SEER / 7.1 HSPF for package heat pump.
Future Efficiencies (2006-2030)	Based on the use of efficiency distributions assuming one of three different *efficiency scenarios*: NAECA, Roll-up, and Shift. Assumed to remain constant over the time period. Resulting *weighted-average* efficiencies are greater than the minimum efficiency allowed by the new standard level.
Total Installed Consumer Cost	Mean values for each efficiency level taken from life-cycle cost analysis. Annual *weighted-average* values are determined through a matrix multiplication based on the efficiency distribution for the given year and the total installed cost corresponding to each incremental efficiency bin within the distribution.
Repair, Maintenance, and Compressor Replacement Costs	Mean values for each efficiency level taken from life-cycle cost analysis. Annual *weighted-average* values are determined through a matrix multiplication based on the efficiency distribution for the given year and the costs corresponding to each incremental efficiency bin within the distribution.
Unit Annual Energy Consumption (UEC)	For any given year, the UEC is determined by multiplying the stock equipment annual energy use by the ratio of the stock equipment efficiency to the efficiency of shipments in that year. Stock energy use and efficiency values are based on the 1997 RECS and the commercial building analysis. Annual shipment efficiencies based on the historical and future efficiency distributions described above.
Electricity Prices	Based on the *weighted-average* marginal electricity price determined in the life-cycle cost analysis.
Escalation of Electricity Prices	2000 EIA Annual Energy Outlook forecasts (to 2020) and extrapolation from 2020 to 2030.
Electricity Site-to-Source Conversion	Conversion varies yearly and is generated by DOE/EIA's NEMS-BRS[g] program (a time series conversion factor; includes electric generation transmission and distribution losses). Conversion factors developed in line with recommendations from the Advisory Committee on Appliance Energy Efficiency Standards.
Discount Rate	7% real.
Present Year	Future expenses are discounted to year 1998.

[g] EIA approves use of the names NEMS (National Energy Modeling System) only to describe an AEO version of the model without any modification to code or data. Since, in this work, there will be some minor code modifications, the name NEMS-BRS is used to describe the model as used here. Chapter 11 on the Utility Impact Analysis and the Environmental Assessment provide more detail on NEMS-BRS.

7.4.2 Trial Standard Levels

NES and NPV results are generated based on Trial Standard Levels (TSL). The TSLs are based on the following: 1) efficiency levels identified in the supplemental Advance Notice of Proposed Rulemaking (ANOPR) published in November, 1999, 2) the efficiency level identified as the Maximum Technologically Feasible level, and 3) a combination of efficiency levels for different product classes that has potentially positive impacts on consumers and the Nation.

Based on the preliminary analyses performed in the supplemental ANOPR, it was observed that uniform efficiency levels for all product classes ranging from 11 to 13 SEER appeared to result in the greatest economic benefits to both consumers and the Nation. Consequently, it was announced in the supplemental ANOPR to further consider and conduct analyses for 11 SEER,12 SEER, and 13 SEER, for each product class.

In selecting candidate standard levels, the Process Rule requires the consideration of equipment which has the most energy efficient combination of design options. The highest efficiency level that is "technologically feasible and economically justified" is known as "Max Tech." The Maximum Technologically Feasible level for each product classis assumed to be 18 SEER. As has been noted in Chapters 4 and 5 of this TSD, in conducting the economic analyses for this "Max Tech" standard level, the greatest production cost multiplier data for each product class and efficiency level available was 15 SEER. Extrapolation of 15 SEER data to 18 SEER was believed to be unjustified. Consequently, the economic analyses for the 18 SEER case are all based on the 15 SEER cost multipliers, therefore, the economic results represent, at best, a lower bound to the actual values.

In addition to considering equipment which has the most energy efficient combination of design options, other criteria for selecting candidate standard levels include: the combination of design options with the lowest life-cycle costs; and standard levels that incorporate noteworthy technologies or fill in large gaps between efficiency levels of other candidate standards levels. In this case the LCC results for different product classes show positive savings for consumers (although not necessarily the minimum savings) and fill in the gap between uniform efficiency levels for the candidate standard levels.

Based on these criteria, NES and NPV results are presented for the following five TSLs:

- **TSL 1**: 11 SEER for all product classes,
- **TSL 2**: 12 SEER for all product classes,
- **TSL 3**: 12 SEER for air conditioners and 13 SEER for heat pumps,
- **TSL 4**: 13 SEER for all product classes, and
- **TSL 5**: 18 SEER for all product classes.

7.4.3 NES Results

The following section provides NES results from the NES spreadsheet models for TSLs 1 through 5 [h]. Results are cumulative to 2030 and are shown as absolute energy savings. It should be reiterated that although efficiency distributions are utilized in the NES spreadsheet models, results are based on *weighted-average* values yielding discrete point-values rather than a distribution of values as in the LCC Analysis.

Table 7.11 and Figure 7.2 show the NES results for the five TSLs based on electricity price forecasts from the *Annual Energy Outlook (AEO) 2000* Reference Case. Three sets of results are provided based on the NAECA, Roll-up, and Shift *efficiency scenarios*. The Shift *efficiency scenario* yields the greatest energy savings while the Roll-up *efficiency scenario* yields the least energy savings.

Table 7.11 Cumulative NES Results based on *AEO2000* Reference Case (2006 - 2030)

	Efficiency Scenario		
	NAECA	**Roll-up**	**Shift**
Trial Standard Level	*Quads*	*Quads*	*Quads*
1	1.7	1.5	1.9
2	3.0	2.9	3.4
3	3.5	3.3	3.9
4	4.3	4.2	4.7
5	8.3	8.3	8.3

[h] NES and NPV results provided in this TSD are different than those results posted on DOE's web site as of June 30, 2000. The NES spreadsheet models available from DOE's web site utilize different site-to-source conversion factors than provided in this Chapter.

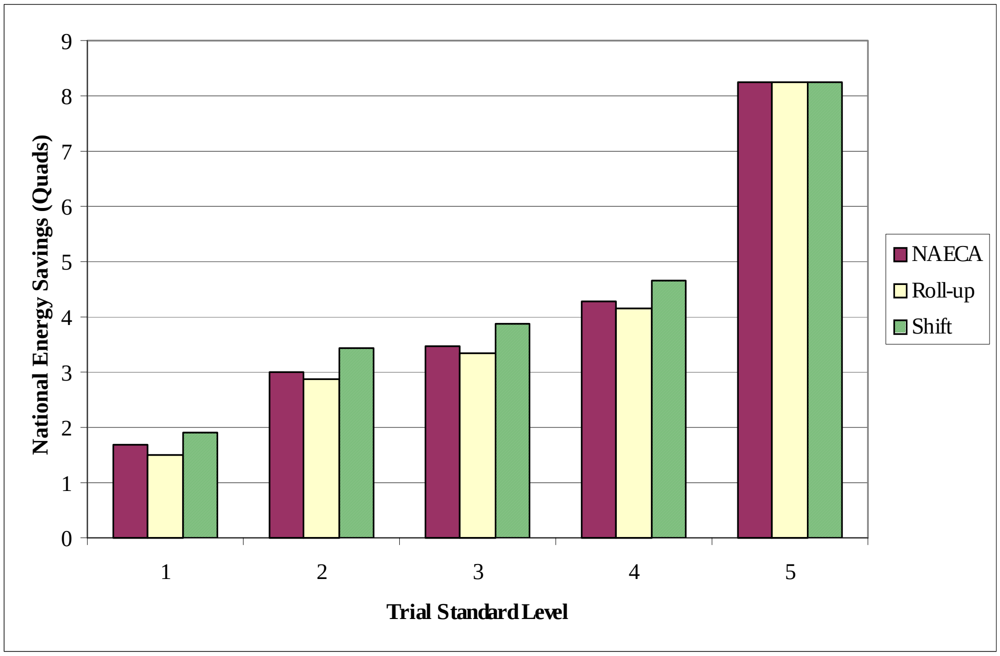

Figure 7.2 Cumulative NES Results based on *AEO2000* Reference Case (2006 -2030)

7.4.3.1 NES Sensitivity to *AEO2000* Forecasts

Sensitivities were conducted on the impact of different *AEO2000* forecasts on the NES. Table 7.12 and Figure 7.3 show the NES results based on the *AEO2000* Low Growth Case while Table 7.13 and Figure 7.4 show the results based on the *AEO2000* High Growth Case. NES results based on the Low Growth Case show slightly lower energy savings relative to the Reference Case forecast while the High Growth Case show slightly greater energy savings.

Table 7.12 Cumulative NES Results based on *AEO2000* Low Growth Case (2006 - 2030)

	Efficiency Scenario		
	NAECA	**Roll-up**	**Shift**
Trial Standard Level	*Quads*	*Quads*	*Quads*
1	1.7	1.5	1.9
2	2.9	2.8	3.4
3	3.4	3.3	3.8
4	4.2	4.1	4.6
5	8.1	8.1	8.1

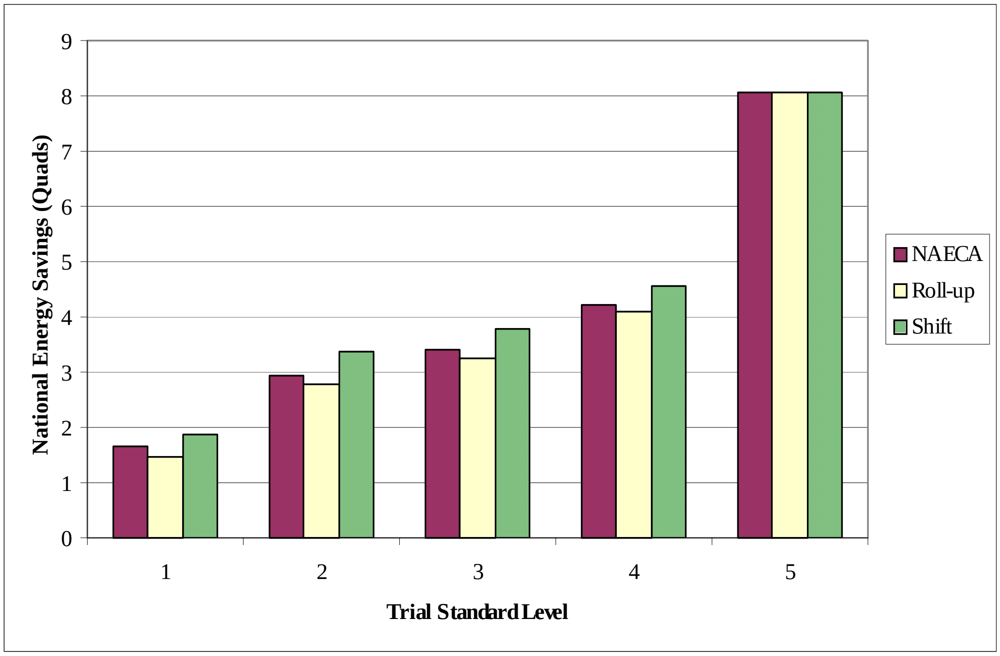

Figure 7.3 Cumulative NES Results based on *AEO2000* Low Growth Case (2006 - 2030)

Table 7.13 Cumulative NES Results based on *AEO2000* High Growth Case (2006 - 2030)

	Efficiency Scenario		
	NAECA	**Roll-up**	**Shift**
Trial Standard Level	*Quads*	*Quads*	*Quads*
1	1.8	1.6	2.0
2	3.2	3.0	3.6
3	3.6	3.5	4.1
4	4.5	4.4	4.9
5	8.7	8.7	8.7

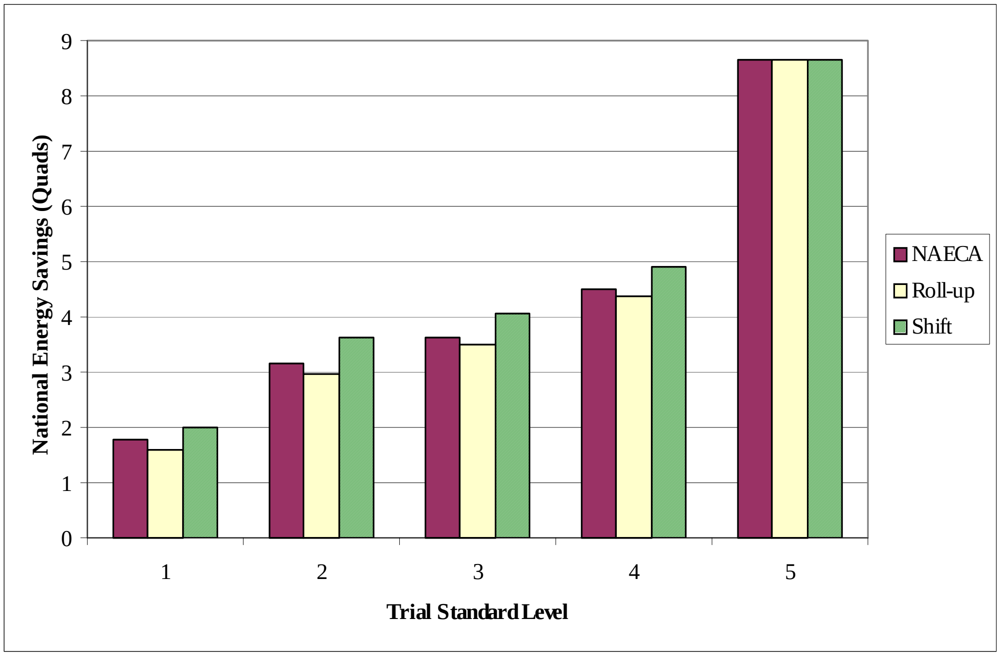

Figure 7.4 Cumulative NES Results based on *AEO2000* High Growth Case (2006 - 2030)

7.4.4 Annual Costs and Savings

As a prelude to providing the NPVs for each TSL, the *annual* equipment cost increases and *annual* operating cost savings at the National level are presented. Figures 7.5 through 7.9 show the changes over time of the non-discounted annual equipment price increases and the non-discounted operating cost savings at each of the five TSLs. The Net Annual Impact, which is the difference between the savings and costs for each year, is also shown in each of the figures. The *Annual Equipment Price Change* is the increase in equipment price for products purchased each year over the period 2005 to 2030. The *Annual Operating Savings* is the savings in operating costs for products purchased, and which have not been retired, for each year over the period 2005 to 2030. The annual costs and savings presented in each figure were determined only according to the NAECA *efficiency scenario* based on the *AEO2000* Reference Case. Note that the NPV is the difference between the *cumulative* annual discounted savings and *cumulative* annual discounted costs.

Figures 7.5 through 7.9 show smaller annual operating cost savings initially compared to increased equipment price costs. Operating cost savings increase with time as more and more equipment meeting the efficiency standard comprises the central air conditioner and heat pump stock. In later years the operating savings start to level off as the equipment stock becomes saturated with systems meeting the standard. Upon closer inspection of the figures, there is a noticeable dip in the operating cost savings occurring in 2020, fourteen years after the standard's effective date. TSL 5 (Figure 7.9) demonstrates this drop more dramatically than any other TSL. The drop in 2020 corresponds to the costs associated with replacing the original compressor that are assumed to take place in the 14th year of the system's life.

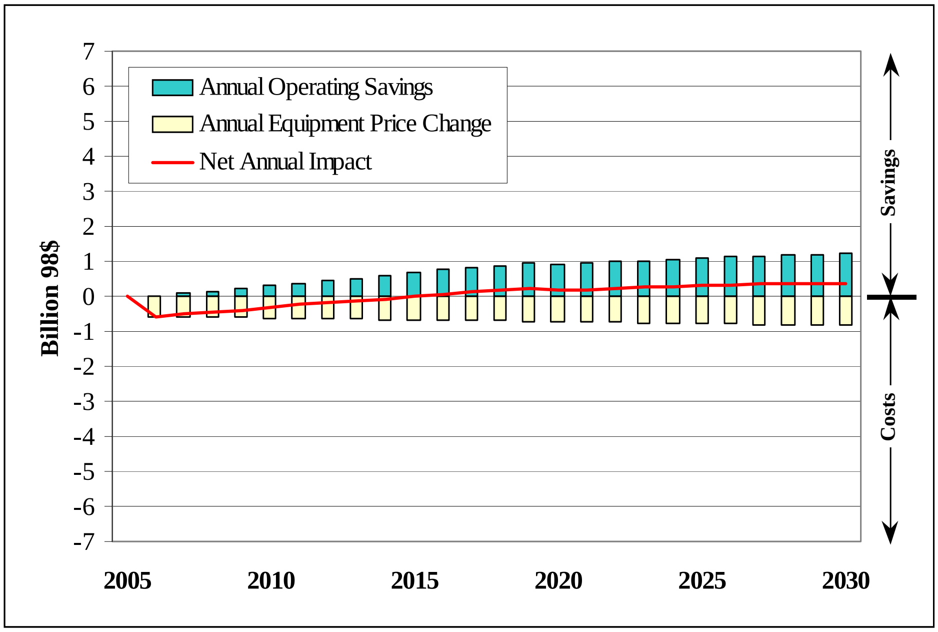

Figure 7.5 National Annual Costs and Savings for TSL 1, NAECA Efficiency Scenario, *AEO2000* Reference Case

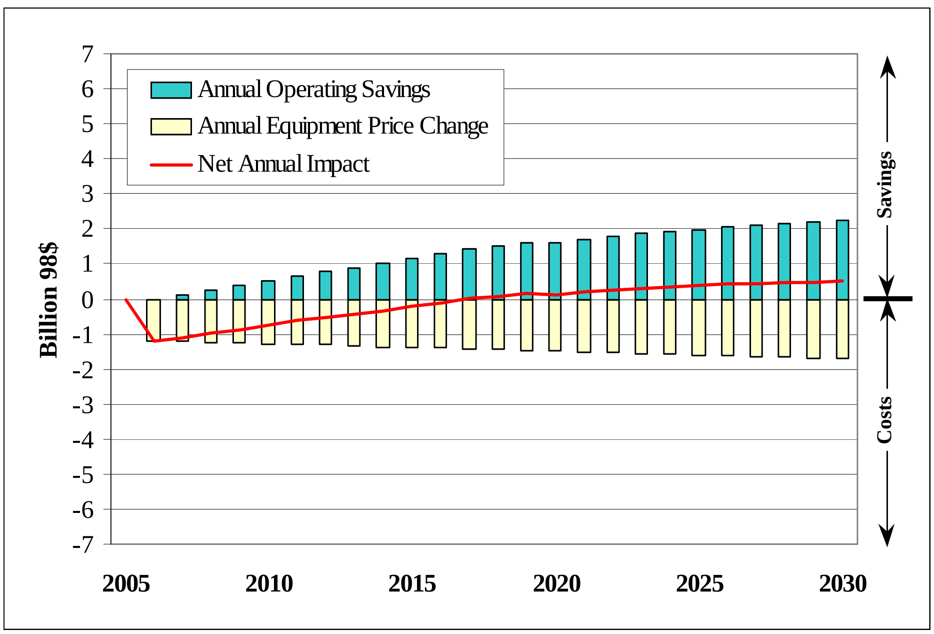

Figure 7.6 National Annual Costs and Savings for TSL 2, NAECA Efficiency Scenario, *AEO2000* Reference Case

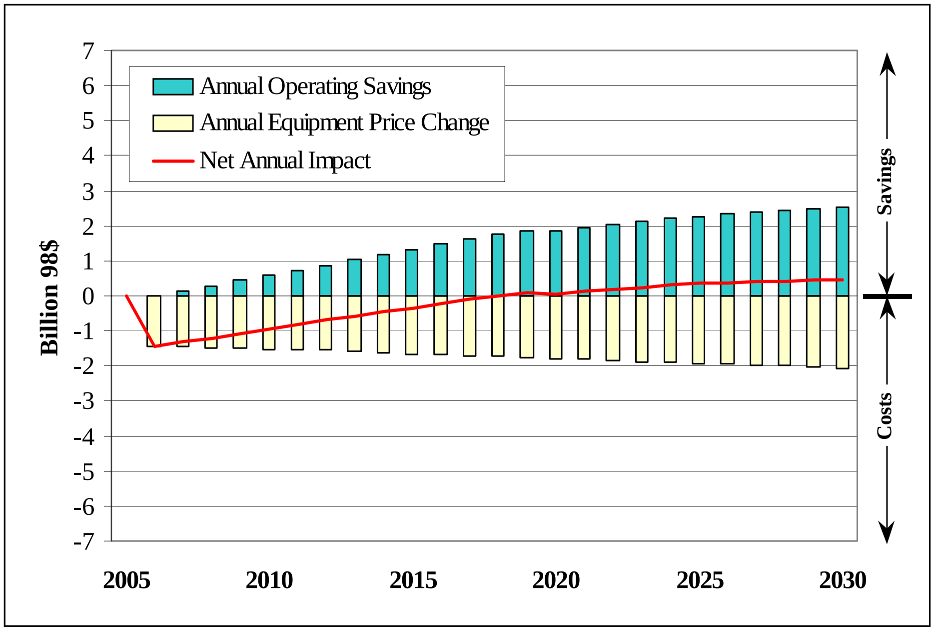

Figure 7.7 National Annual Costs and Savings for TSL 3, NAECA Efficiency Scenario, *AEO2000* Reference Case

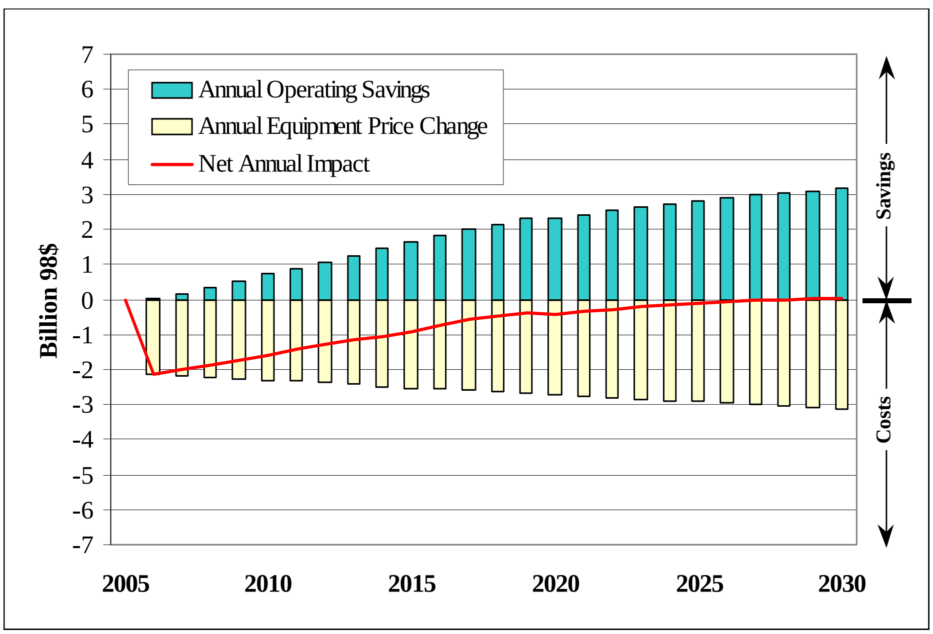

Figure 7.8 National Annual Costs and Savings for TSL 4, NAECA Efficiency Scenario, *AEO2000* Reference Case

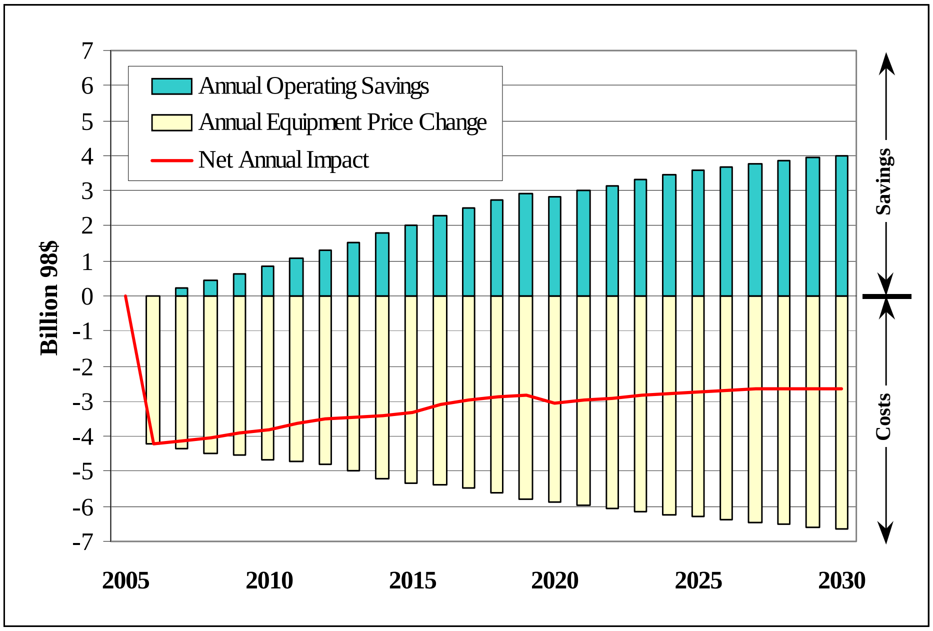

Figure 7.9 National Annual Costs and Savings for TSL 5, NAECA Efficiency Scenario, *AEO2000* Reference Case

7.4.5 NPV Results

The following section provides NPV results from the NES spreadsheet models for TSLs 1 through 5. Results are cumulative to 2030 and are shown as the discounted value of these savings in dollar terms. It should be reiterated that although efficiency distributions are utilized in the NES spreadsheet models, results are based on *weighted-average* values yielding discrete point-values rather than a distribution of values as in the LCC Analysis.

Table 7.14 and Figures 7.10 and 7.11 show the NPV results for the five TSLs based on electricity price forecasts from the *Annual Energy Outlook (AEO) 2000* Reference Case. As with the NES results, three sets of results are provided based on the the NAECA, Roll-up, and Shift *efficiency scenarios*.

In Table 7.14, the total national equipment and operating costs for all central air-conditioning and heat pump equipment under the base case (i.e., in the absence of new efficiency standards) are shown. The total costs are estimated at $381 billion. The range of total costs and NPVs varies from approximately $381 billion total cost for the NAECA and Shift *efficiency scenarios* at TSL 1 and an NPV of $1 billion or less, to $403 billion total cost for all *efficiency scenarios* at TSL 5 and an NPV of −$22 billion. For TSLs 2 and 3, under the NAECA *efficiency scenario* the total costs are $382 billion and $383 billion and the NPVs are −$1 billion and −$2 billion, respectively. Figure 7.10 shows the NPV results in the context of the total equipment and operating costs for central air conditioners and heat pumps.

The NPV is calculated by taking the difference between two relatively large numbers; the baseline cost and the cost under new standards. It is doubtful that a relatively small difference between two large numbers is significant. We have chosen 2% of the base case cost as a significant value for comparison purposes. This value is consistent with the LCC analysis where consumers with life-cycle costs within ±2% of the baseline LCC were considered to be insignificantly impacted by an increase in the standard. Table 7.14 shows the NPV results relative to the total baseline costs, and indicates that the NPVs for TSLs 1 through 4 are relatively small. Figure 7.11 shows the NPV results relative to ±2% of the baseline LCC.

Table 7.14 Cumulative NPV Results based on *AEO2000* Reference Case (2006 - 2030)

	Base Case	Efficiency Scenario								
		NAECA			Roll-up			Shift		
	Total	Total	NPV		Total	NPV		Total	NPV	
TSL	*billion 98$*	*billion 98$*	*billion 98$*	*as % of Base Case Total*	*billion 98$*	*billion 98$*	*as % of Base Case Total*	*billion 98$*	*billion 98$*	*as % of Base Case Total*
1	$381	$381	$0	0.0%	$381	$1	0.2%	$385	$0	-0.1%
2	$381	$382	($1)	-0.3%	$381	$0	0.0%	$388	($3)	-0.9%
3	$381	$383	($2)	-0.5%	$382	($1)	-0.2%	$390	($5)	-1.4%
4	$381	$387	($5)	-1.4%	$386	($4)	-1.1%	$395	($10)	-2.5%
5	$381	$403	($22)	-5.8%	$403	($22)	-5.8%	$407	($22)	-5.8%

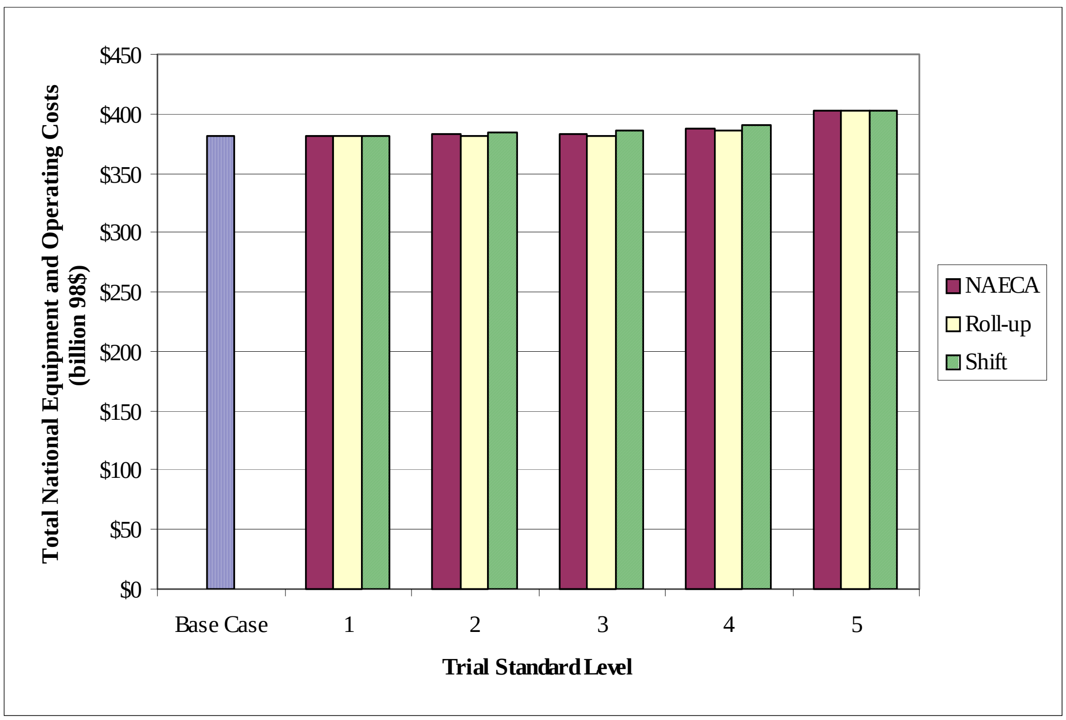

Figure 7.10 Cumulative Total National Equipment and Operating Costs based on *AEO2000* Reference Case (2006 -2030)

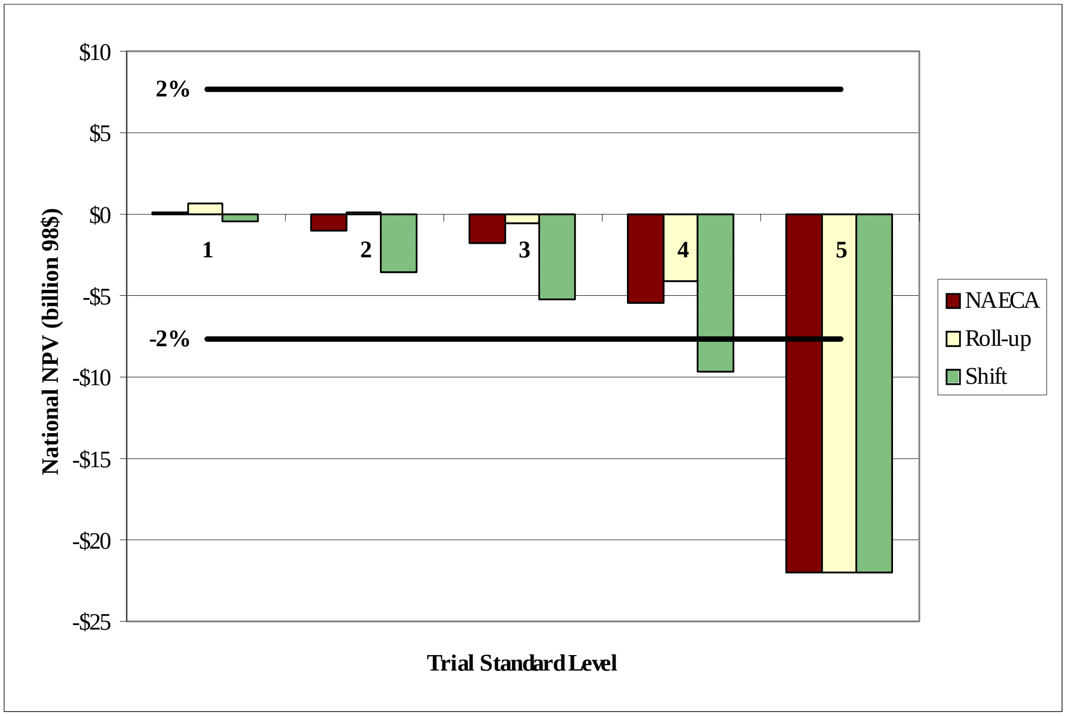

Figure 7.11 Cumulative National NPVs relative to ±2% of Total National Base Case Costs based on *AEO2000* Reference Case (2006 -2030)

7.4.5.1 NPV Sensitivity to *AEO2000* Forecasts

Sensitivities were conducted on the impact of different *AEO2000* forecasts on the NPV. Table 7.15 and Figures 7.12 and 7.13 show the NPV results based on the *AEO2000* Low Growth Case while Table 7.16 and Figures 7.14 and 7.15 show the results based on the *AEO2000* High Growth Case.

Table 7.15 Cumulative NPV Results based on *AEO2000* Low Growth Case (2006 -2030)

	Base Case	Efficiency Scenario								
		NAECA			Roll-up			Shift		
	Total	Total	NPV		Total	NPV		Total	NPV	
TSL	*billion 98$*	*billion 98$*	*billion 98$*	*as % of Base Case Total*	*billion 98$*	*billion 98$*	*as % of Base Case Total*	*billion 98$*	*billion 98$*	*as % of Base Case Total*
1	$369	$369	$0	0.0%	$369	$1	0.1%	$370	($1)	-0.2%
2	$369	$370	($1)	-0.3%	$369	$0	0.0%	$373	($4)	-1.0%
3	$369	$371	($2)	-0.5%	$370	($1)	-0.2%	$375	($5)	-1.5%
4	$369	$375	($6)	-1.5%	$373	($4)	-1.2%	$379	($10)	-2.6%
5	$369	$391	($22)	-5.9%	$391	($22)	-5.9%	$391	($22)	-5.9%

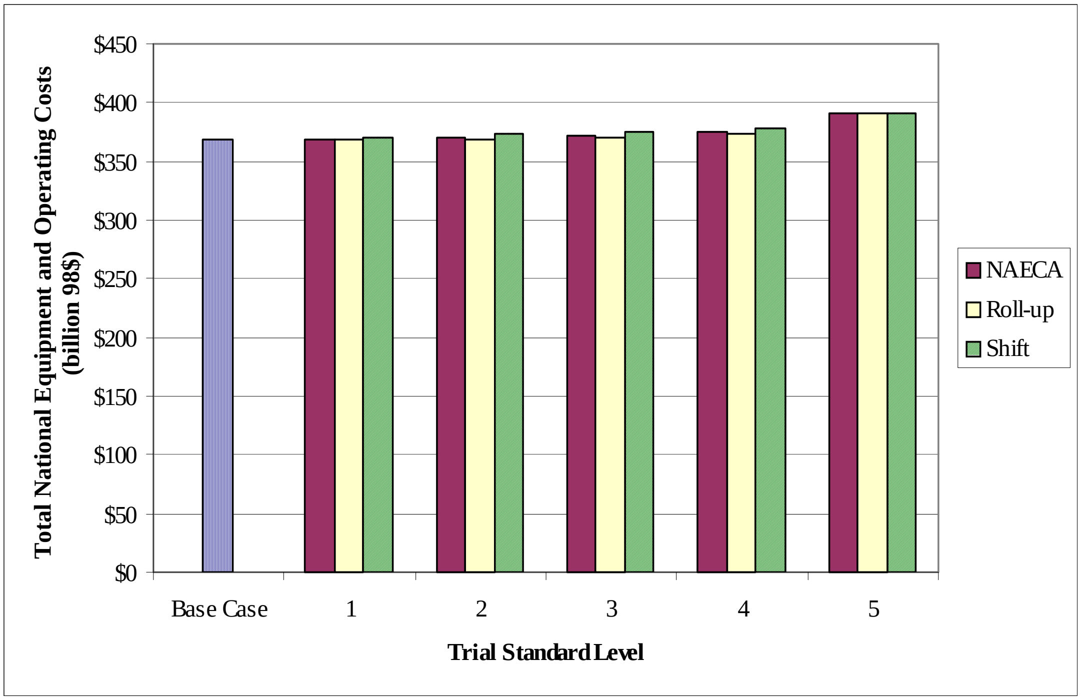

Figure 7.12 Cumulative Total National Equipment and Operating Costs based on *AEO2000* Low Growth Case (2006 - 2030)

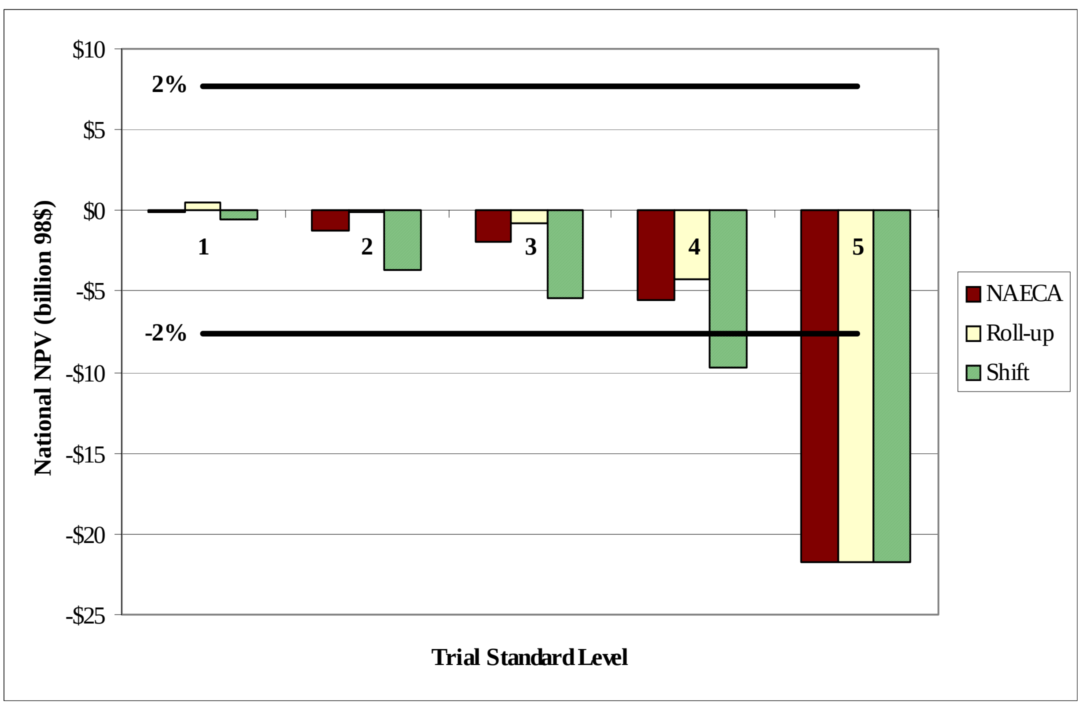

Figure 7.13 Cumulative National NPVs relative to ±2% of Total National Base Case Costs based on *AEO2000* Low Growth Case (2006 -2030)

Table 7.16 Cumulative NPV Results based on *AEO2000* High Growth Case (2006 -2030)

	Base Case	Efficiency Scenario								
		NAECA			Roll-up			Shift		
	Total	Total	NPV		Total	NPV		Total	NPV	
TSL	*billion 98$*	*billion 98$*	*billion 98$*	*as % of Base Case Total*	*billion 98$*	*billion 98$*	*as % of Base Case Total*	*billion 98$*	*billion 98$*	*as % of Base Case Total*
1	$404	$404	$0	0.1%	$403	$1	0.2%	$404	$0	-0.1%
2	$404	$405	($1)	-0.2%	$404	$1	0.1%	$408	($3)	-0.8%
3	$404	$406	($1)	-0.4%	$404	$0	0.0%	$409	($5)	-1.3%
4	$404	$409	($5)	-1.3%	$408	($4)	-0.9%	$414	($10)	-2.4%
5	$404	$426	($22)	-5.4%	$426	($22)	-5.4%	$426	($22)	-5.4%

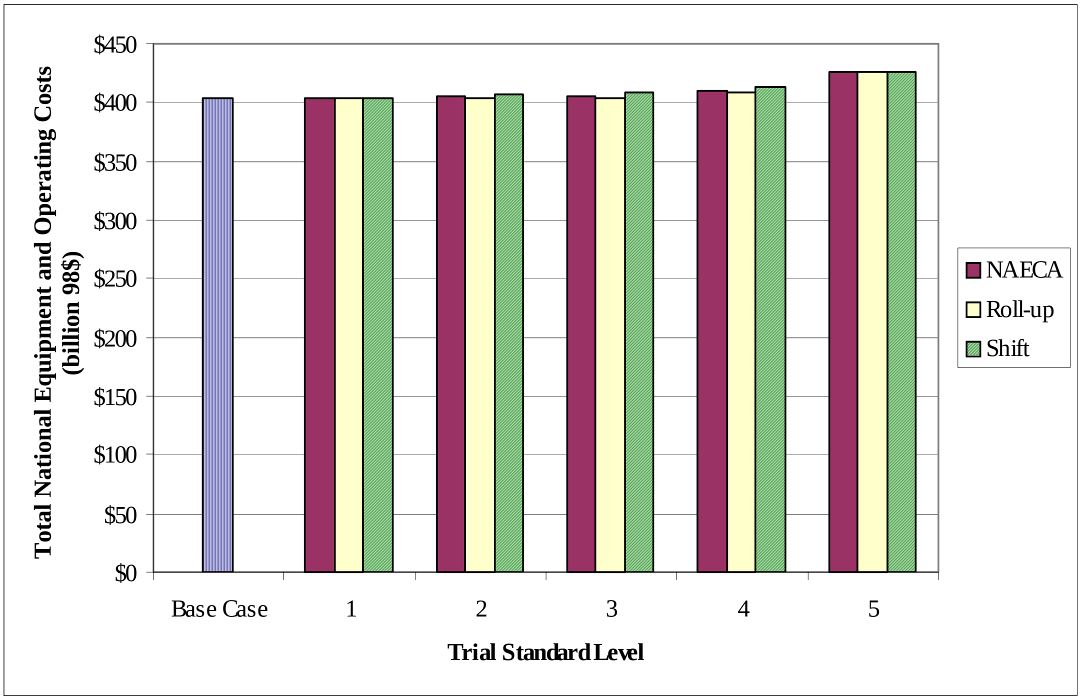

Figure 7.14 Cumulative Total National Equipment and Operating Costs based on *AEO2000* High Growth Case (2006 -2030)

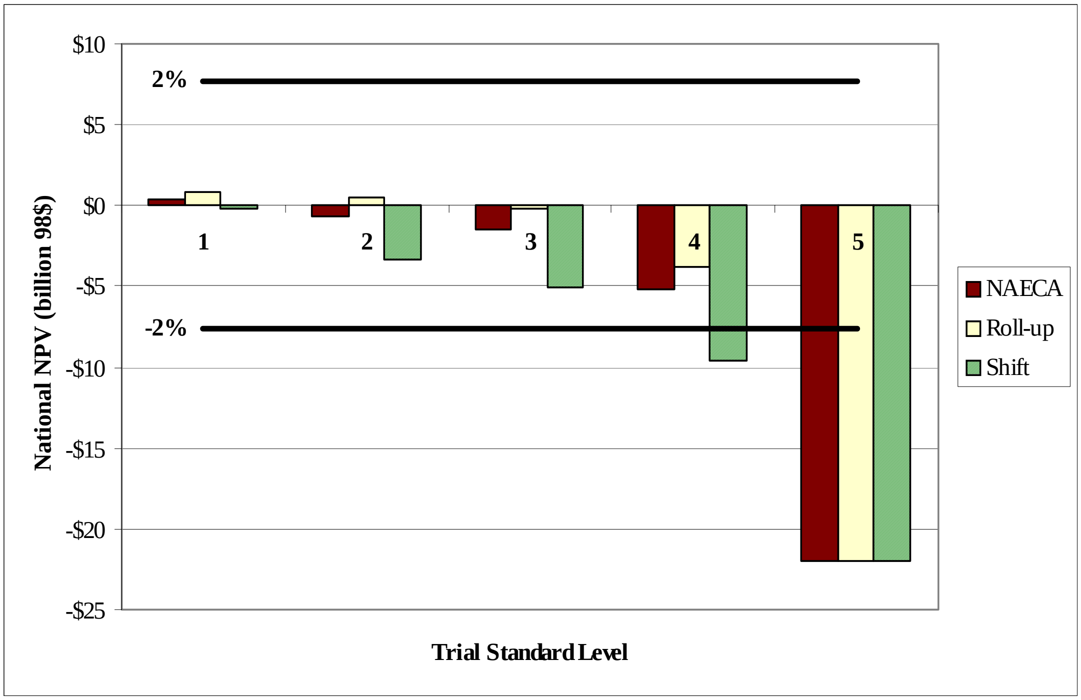

Figure 7.15 Cumulative National NPVs relative to ±2% of Total National Base Case Costs based on *AEO2000* High Growth Case (2006 -2030)

7.4.6 NES and NPV Scenarios

Although in most cases TSLs 1 through 4 exhibit negative NPVs, they are small relative to the total costs to the Nation of owning and operating central air conditioners and heat pumps. Further, NPV is calculated by taking the difference between two relatively large numbers; the baseline cost and the cost under new standards. Associated with each of these total costs is an uncertainty which arises from uncertainty and variability in assumptions in both the LCC and NES analyses. Thus, changes in some key input inputs such as the manufacturer cost, equipment lifetime, discount rate, electricity price forecasts, and cooling load operating hours could turn the negative NPVs into positive values. Consequently, as was performed in the LCC Analysis, key uncertainties are examined as different scenarios.

7.4.6.1 Manufacturer Cost Scenario

Because competitive pressures may likely force manufacturers to produce equipment at costs lower than the shipment-weighted mean estimates provided by ARI, scenarios are performed to determine the impact of different manufacturer cost estimates on the NES and NPV.

A scenario analysis was performed to determine the manufacturer costs at each trial standard level yielding an NPV of zero under the NAECA *efficiency scenario* and *AEO2000*, Reference Case. The "Zero NPV" cost values are compared to the ARI shipment-weighted mean estimates and those from the reverse engineering analysis. Refer to Chapter 5 for the manufacturer cost multipliers derived from the reverse engineering analysis (Section 5.2.4.5, *LCC Scenarios*).

Figures 7.16 through 7.19 show these manufacturing cost comparisons for each of the four product classes. In the case of TSL 1, no change was necessary since the NPV is greater than zero. At TSLs 2 and 3, the "Zero NPV" value lies between the ARI shipment-weighted mean cost figures and the values from the Reverse Engineering Analysis. Specifically, for TSL 2 the "Zero NPV" value represents a decrease of approximately 3% in the ARI manufacturer cost multipliers, while for TSL 3 it represents a decrease of approximately 5% in the ARI multipliers. Assuming that the manufacturer costs will be bounded by the ARI and Reverse Engineering values, it appears that estimated NPVs of zero for TSLs 2 and 3 would result from reasonable decreases in the ARI manufacturer cost estimates.

The adjustments required to attain NPVs of zero for TSLs 4 and 5 resulted in values outside the bounds of the ARI and Reverse Engineering values.

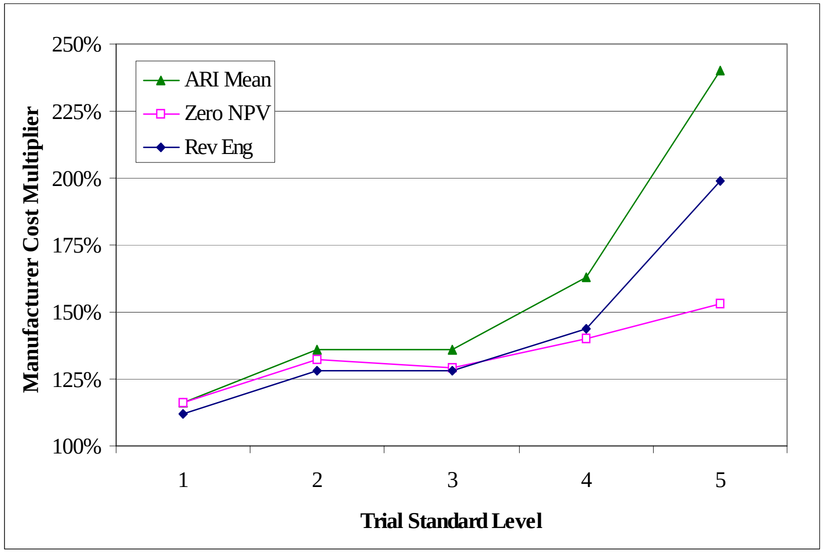

Figure 7.16 Split A/C: Comparison of Manufacturer Cost Multipliers

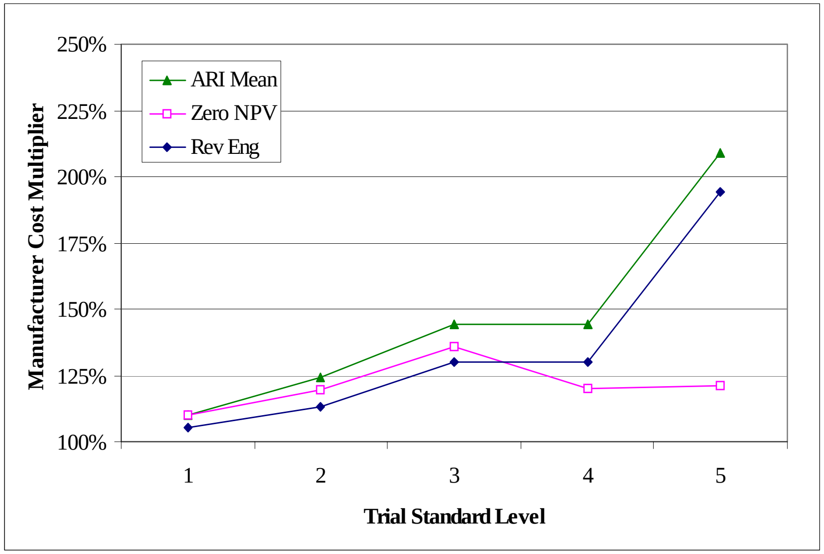

Figure 7.17 Split HP: Comparison of Manufacturer Cost Multipliers

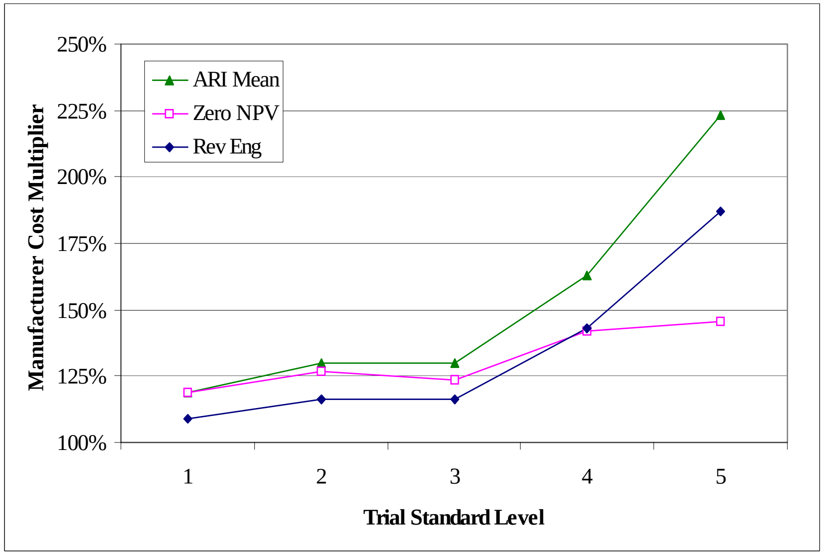

Figure 7.18 Pack. A/C: Comparison of Manufacturer Cost Multipliers

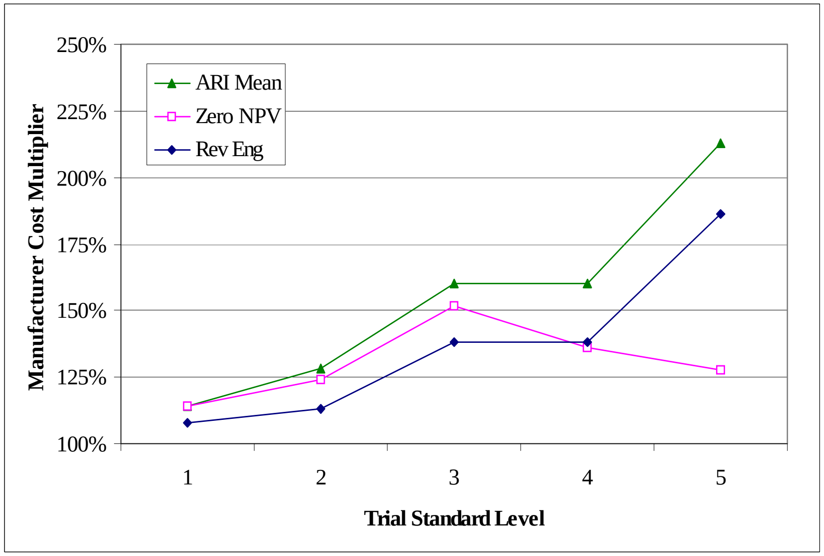

Figure 7.19 Pack. HP: Comparison of Manufacturer Cost Multipliers

To further investigate the sensitivity to manufacturer costs, NPVs are generated based on replacing the ARI-based manufacturer costs with those determined through the reverse engineering analysis. Table 7.17 and Figures 7.20 and 7.21 demonstrate that manufacturer costs based on the reverse engineering analysis yield NPVs which are greater than or equal to zero for TSLs 1 through 4 based on the NAECA *efficiency scenario* and *AEO2000* Reference Case.

Table 7.17 Cumulative NPV Results (2006 -2030): Reverse Engineering Manufacturer Cost Scenario

TSL	Base Case Total *billion 98$*	TSL Total *billion 98$*	TSL NPV *billion 98$*	TSL NPV *as % of Base Case Total*
1	$379	$378	$2	0.4%
2	$379	$377	$2	0.5%
3	$379	$378	$1	0.4%
4	$379	$379	$0	0.0%
5	$379	$390	($10)	-2.7%

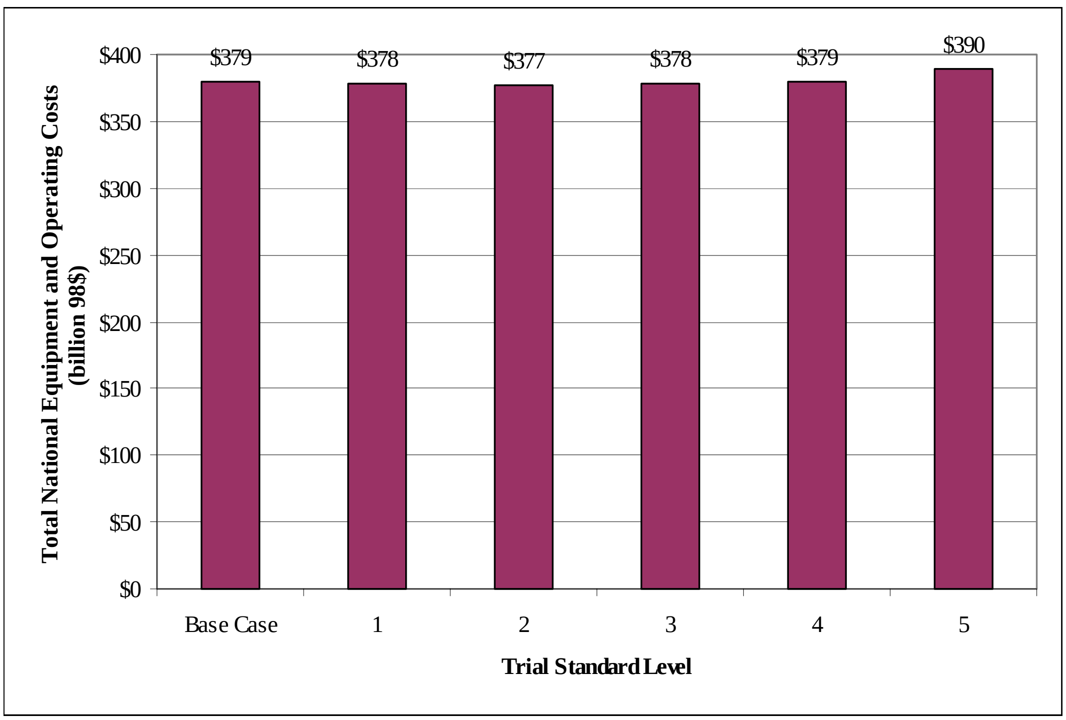

Figure 7.20 Cumulative Total National Operating and Equipment Costs based on Reverse Engineering Manufacturer Cost Scenario (2006 - 2030)

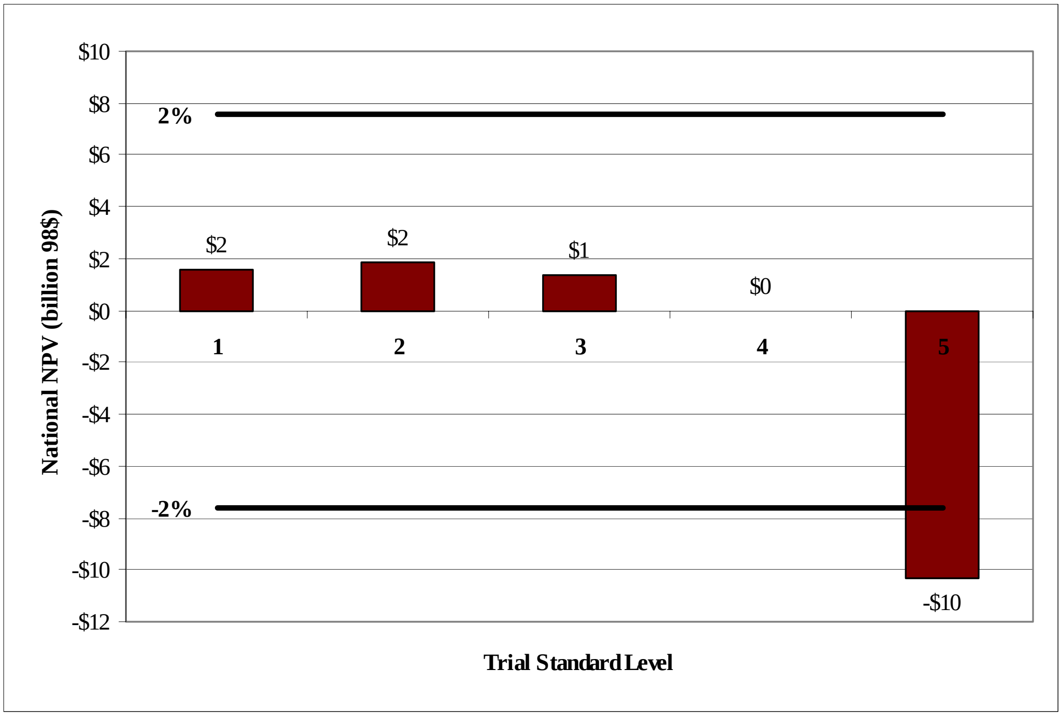

Figure 7.21 Cumulative National NPVs based on Reverse Engineering Manufacturer Cost Scenario (2006 - 2030)

NES results based on the NAECA *efficiency scenario* and *AEO2000* Reference Case under the reverse engineering manufacturer cost scenario are shown in Figure 7.22.

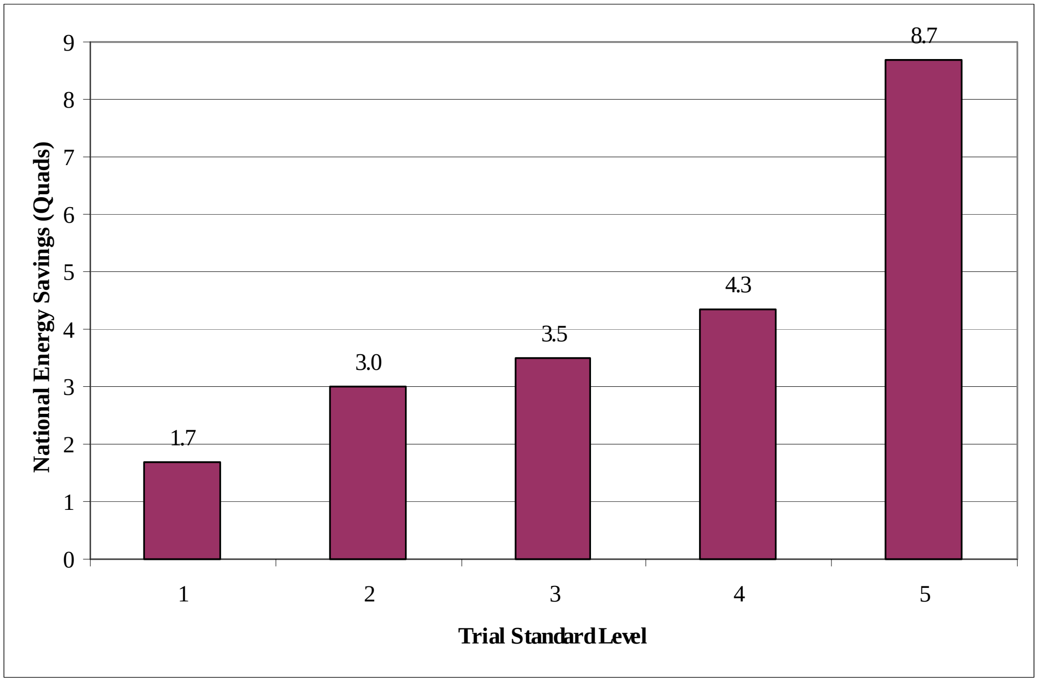

Figure 7.22 Cumulative NES Results based on Reverse Engineering Manufacturer Cost Scenario (2006 - 2030)

7.4.6.2 Lifetime Scenario

A shorter lifetime is investigated based on the assumption that most, if not all, consumers when faced with replacing a failed compressor would choose to replace the entire system rather than replace the compressor in a relatively old system. In order to determine the impact of a shorter lifetime, a lifetime scenario is investigated where a retirement function yielding an average lifetime of 14 years is used instead of the function that results in a 18.4 year average life. In addition, compressor replacement costs are no longer considered.

Table 7.18 and Figures 7.23 through 7.24 show the NPV results based on the NAECA *efficiency scenario* and the *AEO2000* Reference Case when the "18.4 year" retirement function is replaced with one yielding a 14 year average life. The results based on the 14 year average lifetime are very similar to those based on the "18.4 year" retirement function (e.g., small negative NPVs result for TSLs 1 through 4).

Table 7.18 Cumulative NPV Results (2006 - 2030): 14-year Average Lifetime Scenario

	Base Case Total	TSL Total	TSL NPV	
TSL	*billion 98$*	*billion 98$*	*billion 98$*	*as % of Base Case Total*
1	$363	$364	$0	0.0%
2	$363	$365	($2)	-0.5%
3	$363	$366	($3)	-0.8%
4	$363	$370	($7)	-1.9%
5	$363	$389	($25)	-6.9%

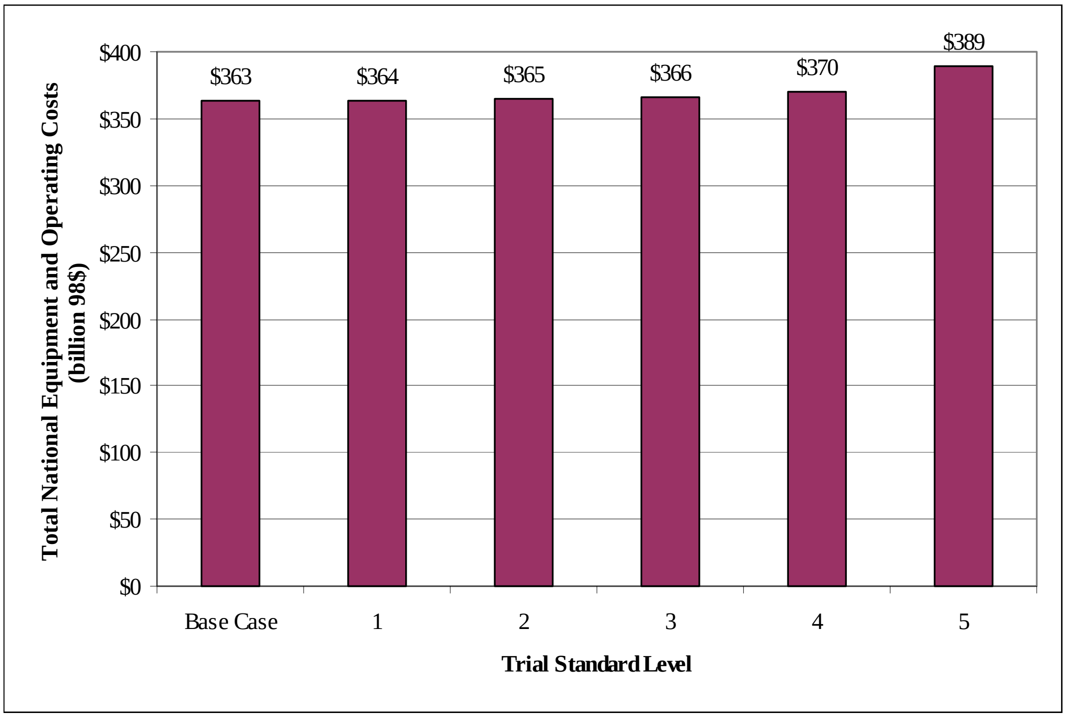

Figure 7.23 Cumulative Total National Equipment and Operating Costs based on 14-year Average Lifetime Scenario (2006 -2030)

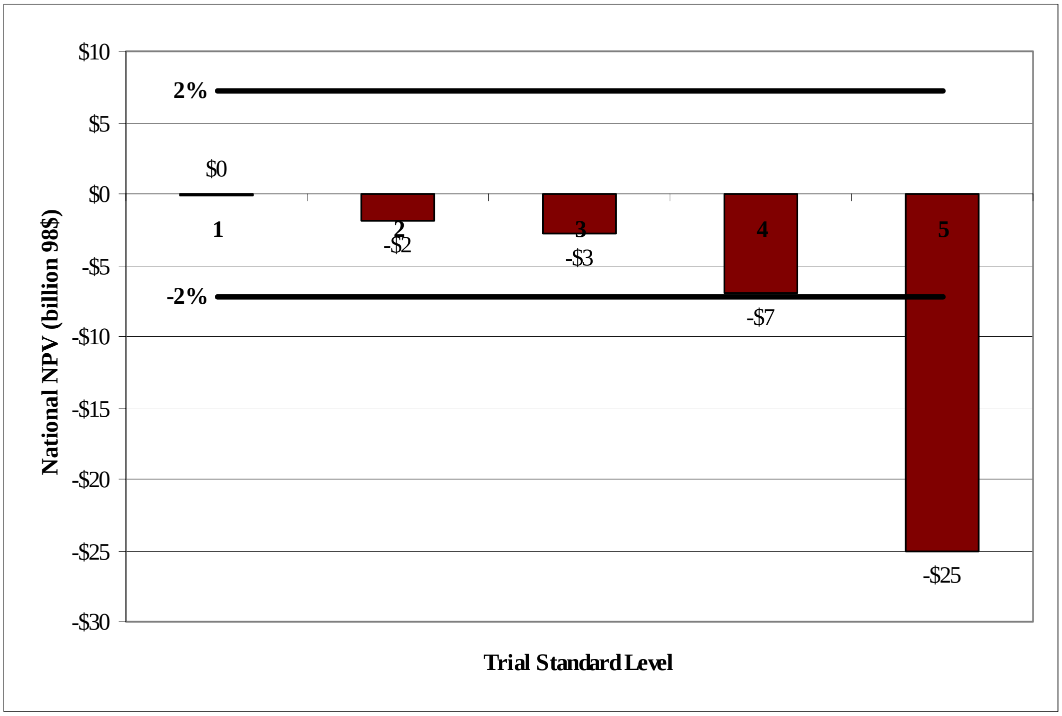

Figure 7.24 Cumulative National NPVs based on 14-year Average Lifetime Scenario (2006 -2030)

NES results based on the NAECA *efficiency scenario* and *AEO2000* Reference Case under the 14-year average lifetime scenario are shown in Figure 7.25.

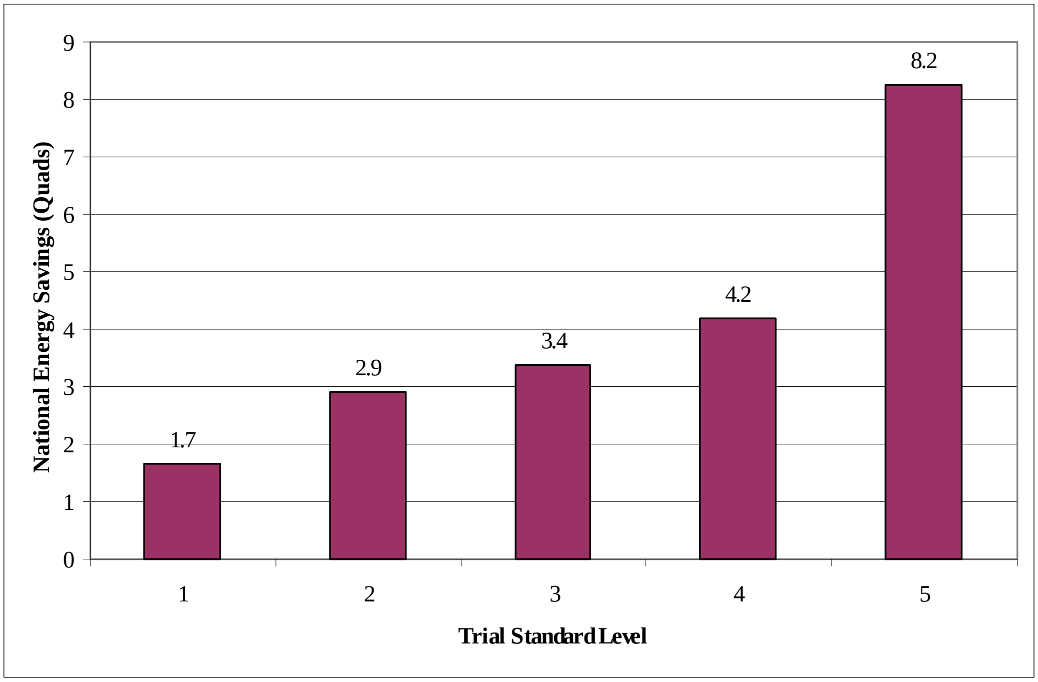

Figure 7.25 Cumulative NES Results based on 14-year Average Lifetime Scenario (2006 - 2030)

7.4.6.3 Discount Rate Scenario

To determine how sensitive the NPV is to discount rate, results were generated with a discount rate of 3% rather than a value of 7%. A value of 7% has been traditionally used to represent the Nation's societal discount rate. In "Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements", the Office of Management and Budget (OMB) recently advised Federal agencies to use the 3% value as a sensitivity for calculating the national economic impacts of regulatory policies. Table 7.19 and Figures 7.26 and 7.27 provide the NPV results based on a discount rate of 3% under the NAECA *efficiency scenario* and *AEO2000* Reference Case. Note the dramatic increase in the total national costs of operating central air conditioners and heat pumps in the base case ($712 billion at a 3% discount rate as opposed to $381 billion at a 7% discount rate). As a a result, all NPVs are less than 1% of the total base case national costs (with the exception TSL 5).

It is important to note, that the discount rate described here is not the same as the market discount rate used in describing consumer decisions and, in turn, forecasting shipments (refer to Chapter 6, Section 6.3.4.2, *Market Discount Rate*). Thus, a change in the discount rate from 7% to 3% does not impact shipment forecasts.

Table 7.19 Cumulative NPV Results (2006 - 2030): 3% Discount Rate Scenario

TSL	Base Case Total	TSL Total	TSL NPV	
	billion 98$	*billion 98$*	*billion 98$*	*as % of Base Case Total*
1	$712	$708	$3	0.5%
2	$712	$708	$4	0.5%
3	$712	$708	$3	0.4%
4	$712	$714	($3)	-0.4%
5	$712	$746	($35)	-4.9%

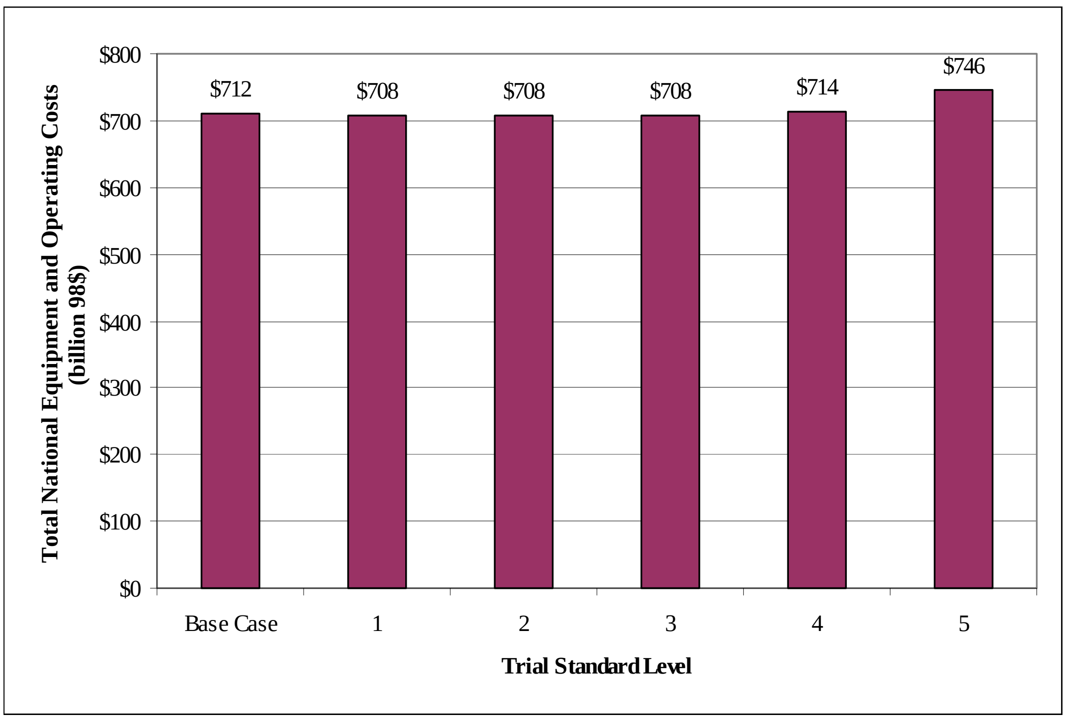

Figure 7.26 Cumulative Total National Equipment and Operating Costs based on 3% Discount Rate Scenario (2006 -2030)

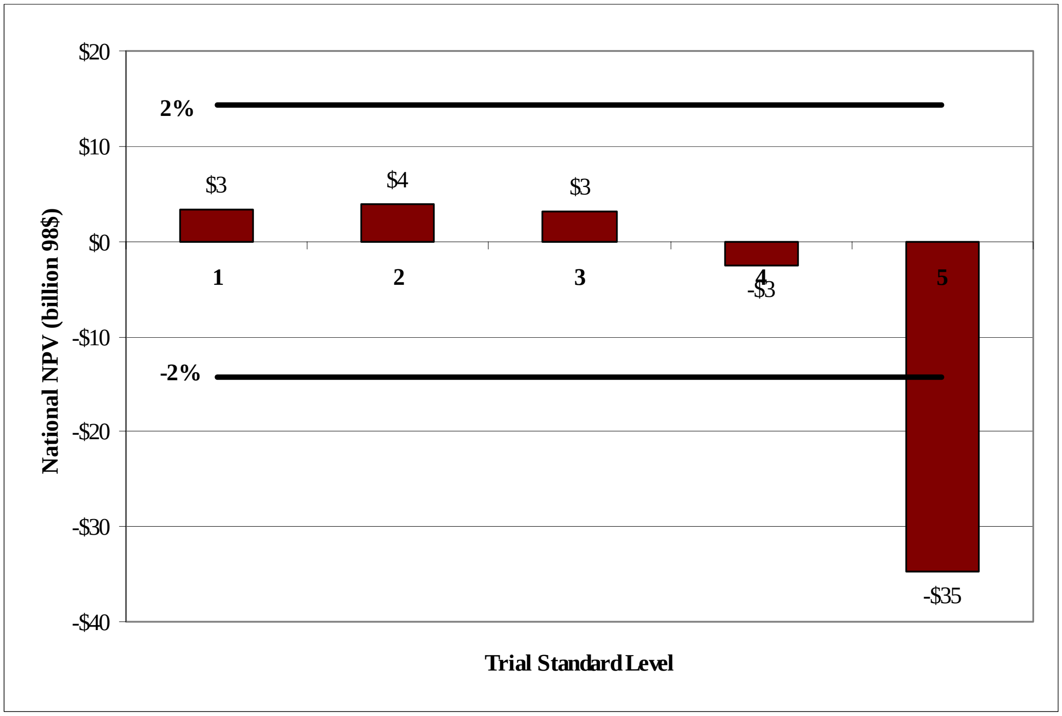

Figure 7.27 Cumulative National NPVs based on 3% Discount Rate Scenario (2006 - 2030)

NES results based on the NAECA *efficiency scenario* and *AEO2000* Reference Case under the 3% discount rate scenario are shown in Figure 7.28.

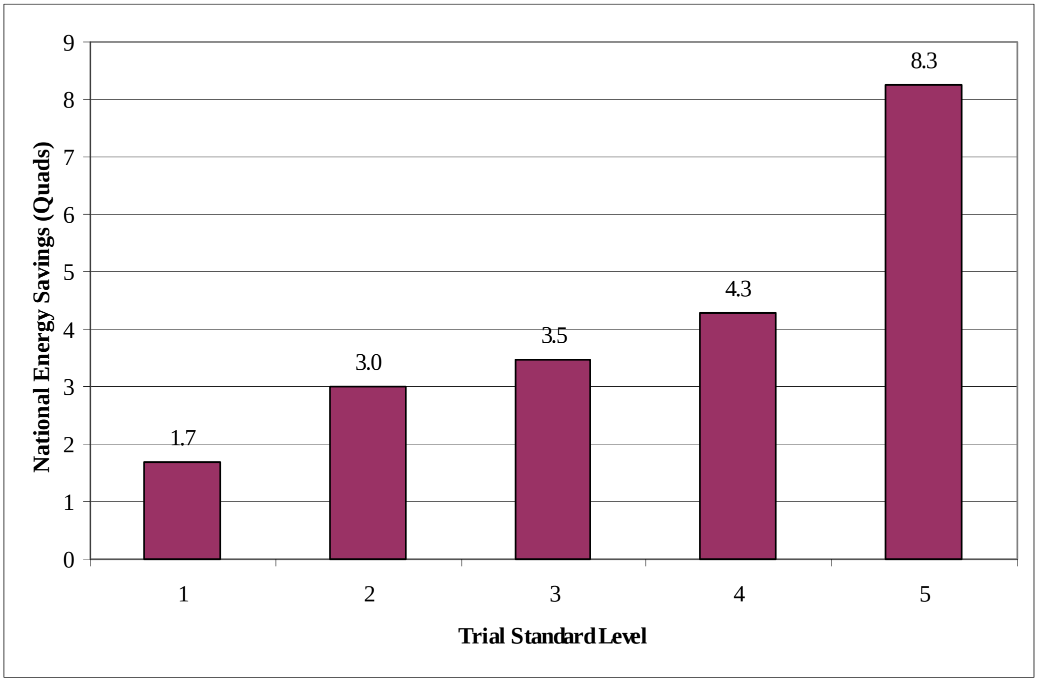

Figure 7.28 Cumulative NES Results based on 3% Discount Rate Scenario (2006 - 2030)

7.4.7 NES and NPV Results as shown in Spreadsheet Model

To illustrate how the NES and NPV results are presented in the NES spreadsheet models, Figures 7.29 through 7.31 are provided for the case of a 12 SEER efficiency-level for split system central air conditioners. In this example, Figure 7.29 shows the cumulative national electricity savings from the assumed effective date of the standard (2006) to three specific dates; 2010, 2020, and 2030. Figure 7.30 presents the discounted value of savings and costs to the year 1998 for the time period 2006 to 2030 (in billion 1998$). The value of total energy savings is $5.73 billion, the total equipment cost is $7.06 billion, and the resulting net present value is -$1.32 billion. The corresponding ratio of benefits to costs is 0.81.

	Energy Saving in Quads				
	Total	Elec	Gas	Oil	LPG
from 2006					
to 2010	0.11	0.11	0.00	0.00	0.00
to 2020	0.78	0.78	0.00	0.00	0.00
to 2030	1.83	1.83	0.00	0.00	0.00

Figure 7.29 NES for Split System A/C based on a 12 SEER Efficiency-Level

CAC/HP Standards in 2006:	12 SEER

Cost and Net Present Values (in billion 1998$)	
Cumulative for Split A/C Purchased from 2006 to 2030	
Discounted at 7% to year 1998	
Total Operating Savings	5.73
Total Equipment Cost	7.06
Net Present Benefit	-1.32
Benefit/Cost Ratio	0.81

Figure 7.30 NES for Split System A/C based on a 12 SEER Efficiency-Level

Figure 7.31, below, illustrates the typical pattern of national savings and costs resulting from standards over time. This figure is nearly identical to the information shown previously in Figures 7.5 through 7.9. The heavy line running just below the energy savings bars indicates the undiscounted net national consumer impact of standards over time. Figure 7.31 shows the nature of net savings for a 12 SEER standard for split system central air conditioners relative to the baseline. Alternate standard levels would yield different values. Appendix E contains the detailed results for all standard level and product class combinations.

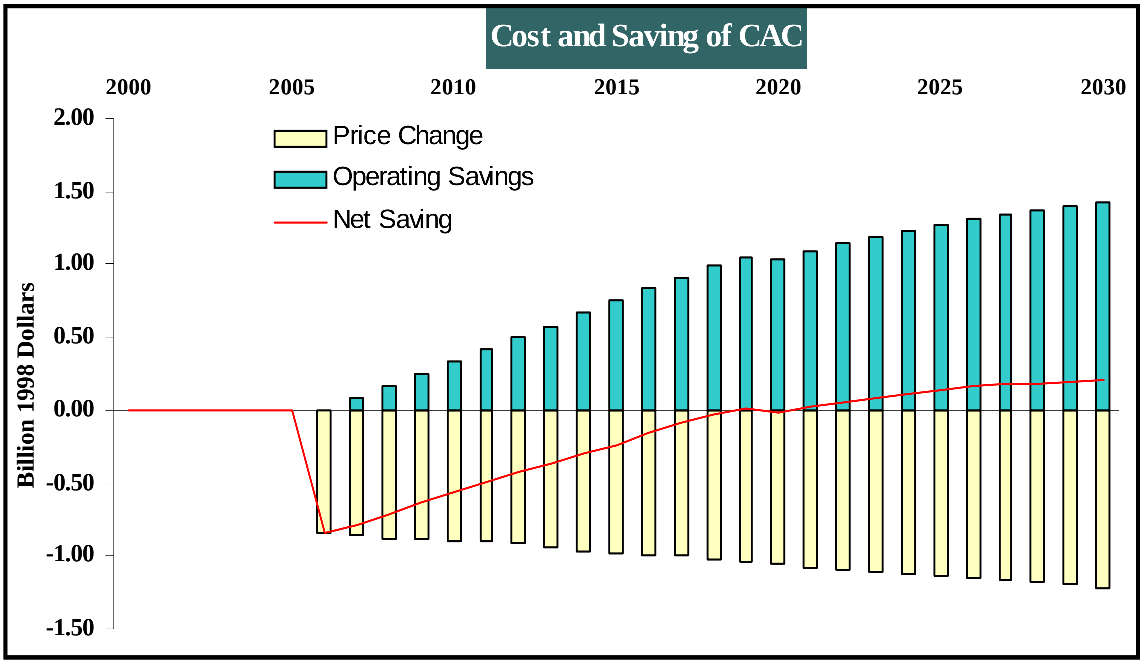

Figure 7.31 Annual Values of a 12 SEER Efficiency-Level for Split A/C

7.5 USER INSTRUCTIONS FOR NES SPREADSHEET

It is possible to examine and reproduce the detailed results obtained in this part of the analysis using a Microsoft Excel spreadsheet available on the U.S. Department of Energy Office of Codes and Standards website at: http://www.eren.doe.gov/buildings/codes_standards/.

The NES spreadsheet allows the user to perform NES and NPV analyses of split or single package central air conditioner or heat pumps. The Shipments Model, as described in Chapter 6, is incorporated into the NES spreadsheet. The spreadsheets posted on the DOE website represent the latest versions of the applicable models, and have been tested with version of Excel 2000 and lower. The NES spreadsheet or workbook consists of the following worksheets:

Welcome NES This worksheet is the main user page. It provides six list boxes that allow the user to choose a range of scenarios, plus two additional input boxes (highlighted in yellow) where the user can type in a desired input value directly. The five list boxes allow the user to choose the following: 1) growth projection for energy prices and housing, 2) the standard case design, 3) the type of system (i.e., split or package air conditioner or heat pump) to be analyzed, 4) the price option (i.e., ARI or Rev Eng), 5) the price projection and 6) the *efficiency scenario*. The additional input boxes allow the user to change the discount rate and the start year of the standard. For heat pumps, the user can select different cooling and heating efficiency values (i.e., SEER and HSPF) than the default values. Different elements of the national energy savings are illustrated, including total electricity savings, the dollar value of energy savings, and the benefit/cost ratio for the standard case.

Welcome Ship This worksheet is the user page for specifying the type of price/income elasticity that should be used in the Shipments Model. Shipments information is summarized here with the following figures and tables: 1) a figure showing the historical and forecasted shipments for the type of system selected in the **Welcome NES** worksheet, 2) tables summarizing the average impacts on new shipments, new sales, mean equipment age, mean lifetime, repairs, and early replacements from the standard level, 3) a figure showing the Shipment Model's fit to historical data, and 4) figures showing how the mean equipment age and the age of products retired change over time.

Inputs The **Inputs** sheet contains the detailed parametric inputs to the shipments forecast model. These inputs include the elasticities and initial market shares for each of the market segments. The user can change the individual model elasticities which are highlighted in yellow. Note, that if one makes changes in elasticities on the **Input** sheet, this likely will affect the historical base case. The non-highlighted cells in this worksheet are protected to help the user avoid erroneous modifications.

Shipment Forecast The **Shipment Forecast** worksheet provides the detailed estimates and accounting of central air conditioner or heat pump populations. This sheet contains the core of the shipments calculation and the tables which specify the estimates of each type of central air conditioner or heat pump purchase. The tables in the sheet provide accounting of each type of central air conditioner or heat pump ownership category, and each type of central air conditioner or heat pump for each age category of central air conditioner or heat pump. This worksheet also calculates the standard case energy use and monetary costs. The sheet contains the estimates of the population of central air conditioners in each age category and each forecast year for the standard case selected by the user on the Welcome worksheet. It then uses this information to calculate the standard case energy consumption and operating cost. It also computes the operating and equipment costs for each year.

Base Case The Base Case worksheet stores the base case energy use and monetary costs (i.e., what is projected to happen in the absence of an efficiency standard). The sheet contains the base case estimates of the population of central air conditioners or heat pumps in each age category and in each year. It also stores the base case energy consumption and operating cost for each year. The data in the Base Case worksheet is copied from the Shipment Forecast worksheet when the user clicks the Reset Base Case button on the Welcome NES worksheet.

Savings This worksheet calculates the difference between the standards case and base case energy use (i.e., National Energy Savings) and monetary costs (i.e., Net Present Value) forecasts.

Econ Inputs This worksheet calculates and summarizes the economic inputs (i.e., product price and operating cost) necessary for determining the base case and standards case monetary costs. Costs are determined on an annual basis for each of the four primary product classes.

Energy Inputs This worksheet calculates and summarizes the energy use data necessary for determining the operating costs for the **Econ Inputs** worksheet. Energy use information is calculated by product class and Census Division (for the residential market only). Efficiency distributions are incorporated into this worksheet from **MS Efficiency** worksheet that is described below.

Projections Contains the tables that provide the energy price and housing data for different projection scenarios. These scenarios include the *Annual Energy Outlook (AEO) 2000* high-growth, low-growth and reference cases (http://www.eia.doe.gov/oiaf/aeo2000/homepage.html). There is also an option for constant energy prices, and an estimate from the Gas Research Institute (GRI). Also included here are the weighted-average marginal electricity prices.

Engineering This worksheet contains the data on total installed prices and annual repair, maintenance, and compressor replacement costs for central air conditioners and heat pumps meeting different standard levels. The data from this sheet are used to calculate the per unit installation price and repair, maintenance, and compressor replacement costs for each standard level. The type of system selected in the **Welcome** worksheet dictates which set of data are analyzed.

MS Region Product This worksheet provides the product type market shares as a function of year.

MS Efficiency Here we provide the calculation of the market shares of the different efficiency levels as a function of year.

MS New Homes Here we provide the market share calculation for the new housing market based on the logit probability of purchase model. A logit probability of purchase model estimates how purchase probabilities change as a function of price, operating cost savings, and income changes.

MS Early Repl Here we provide the market share calculation for the early replacement market based on the logit probability of purchase model, and an initial probability of purchase that is a linear function of central air conditioner or heat pump age.

MS non-owner This sheet provides the market share calculation for the non-owners who purchase central air conditioners and heat pumps and become new equipment owners. Note that this market is currently modeled through a remodel market that is correlated with the new housing market. But we keep this market in the spreadsheet for the benefit of users who may want to examine alternatives for modeling the purchases of the non-ower market.

MS Replace This worksheet calculates the probability of replacement vs. repair as a function of economic decision parameters for each year. The annual probability of replacement is calculated for each age category of central air conditioner or heat pump.

Retirement Function The worksheet shows the fraction of central air conditioners or heat pumps that are expected to retire as a function of years since the central air conditioner or heat pump was purchased new. (Repairs may extend the life of the equipment and are accounted for in the worksheet **Shipment Forecast**.)

The NES spreadsheet provide an estimate of the national energy and monetary savings of different air conditioner and heat pump efficiency standards as well as shipments forecasts. The spreadsheet uses estimates of future air conditioner or heat pump sales and stock from the Shipments Model within the spreadsheet for the chosen standard level to estimate potential savings from the standard. It also calculates the dollar value of these savings year-by-year. It estimates the amount of energy that will be saved at the source by considering transmission and distribution losses. It also calculates the monetary savings that can result from a standard and the net present value of such savings. The following provides basic instructions for operating the NES spreadsheets.

1. Once you have downloaded the NES files from the Web, open one of the files using Excel. At the bottom, click on the tab for the worksheet labeled **Welcome NES**.

2. The screen will display two tables (*Energy Savings in Quads* and *Cost and Net Present Values*) and a chart (*Cost and Savings of CAC/HP).* (Use Excel's **View/Zoom** commands to change the size of the display to make it fit your monitor.)

3. To run different scenarios, simply select the energy price and housing projection, the standard level, the price option (either based on ARI or reverse engineering manufacturer costs), the type of system (either split or package), and the *efficiency scenario* from the appropriate list box. The user may also input values for the discount rate and start year by directly typing the desired values into the appropriate input box, highlighted in yellow.

   With regard to the standard case design, the user can input either a single tier efficiency standard or a two tier efficiency standard. If a single tier standard is desired, the tier #1 and tier #2 efficiencies as well as the tier #1 and tier #2 start years need to be set to identical values. If a two tier standard is desired, the tier #1 and tier #2 efficiencies and start years should be set to different values. The tier #1 and tier #2 efficiencies are drawn from a list of options ranging from 10 to 18 SEER while the tier #1 and tier #2 start years require the user to type in a value.

   The user is also allowed to customize the SEER/HSPF combination for split or package heat pumps. In the table entitled “Heat Pump Standard Level Customization”, the base levels are shown in the first two columns. The last two columns provide the option of defining new SEER and HSPF values for the particular standard level of interest. For example, to achieve the same national energy savings for level 2 (12 SEER and 7.4 HSPF) but with a lower SEER value and a higher HSPF value, the user simply needs to type in the desired SEER and HSPF values in the customized input cells immediately to the right of the base level values. The user will need to go through a “trial and error” sequence to determine the exact SEER and HSPF values that will result in energy savings equivalent to the base level values.

4. Select the standard level for the Base Case (10 SEER). Click the **Reset Base Case** button to store the base case information in the Base Case worksheet. Then select the standard level of interest.

5. There are two *calculation buttons* for determining the energy savings and NPVs for a particular standard case.

   The first button is called **Calculate Results Relative to 10 SEER**. This is the button that is recommend for use. Simply click on this button to calculate the energy savings and NPV results for the defined standard case. Clicking on this button generates results that are relative to a base case design where 10 SEER is the minimum efficiency standard (9.7 SEER for package systems).

   The second button, **Reset Base Case**, should only be used if the user want to generate results relative to a base case design that IS NOT based on a minimum standard of 10 SEER. For example, a user might want to generate results for a 12 SEER standard relative to an 11 SEER standard. If this were the case, the user would need to specify both tier #1 and tier #2 efficiency levels at 11 SEER for a particular start year. Then the user would need to click on the **Reset Base Case** button. Then the user would need to change the efficiency levels to 12 SEER. After changing the efficiency levels, the energy savings and NPV results generated would reflect the difference between 11 and 12 SEER standards.

The spreadsheets provide output as charts, summary statistics, and detailed tables. Summary figures and charts are provided on the **Welcome NES** worksheet. For each year from the standard start date to 2030, the *Costs and Savings of CAC/HP* chart shows the additional cost (labeled *Price Change*) to consumers to purchase the higher efficiency central air conditioners or heat pumps mandated by the standard, vs. the amount saved by consumers in reduced energy (labeled *Operating Savings*). The net saving to consumers is the difference between the money saved in energy bills minus the additional money spent on higher efficiency space-conditioning equipment. This net saving is shown as a red line labeled *Net Saving* on this chart.

REFERENCES

1. Neme, C., J. Peters, and D. Rouleau, Promoting High Efficiency Residential HVAC Equipment: Lessons Learned from Leading Utility Programs. In *ACEEE 1998 Summer Study on Energy Efficiency in Buildings*. 1998. Asilomar, CA: American Council for an Energy-Efficient Economy, 2: p. 2.153-2.164.

2. Bucher, M.E., C.M. Grastataro, and W.R. Coleman, Heat Pump Life and Compressor Longevity in Diverse Climates. *ASHRAE Transactions*, 1990. 96(1): p. 1567-1571.

3. U.S. Department of Energy-Energy Information Administration, *A Look at Residential Energy Consumption in 1997*, 1999. Washington, DC. Report No. DOE/EIA-0632(97). EIA website: <http://www.eia.doe.gov/pub/pdf/consumption/063297.pdf>